Soils: The Foundation of New Forests in Ontario

Hybrid Poplar

1984

Ontario
Ministry of Natural Resources
Hon. Alan W. Pope
Minister
John R. Sloan
Deputy Minister

ISBN 0-7743-9159-6

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Printed in Ontario, Canada

Additional copies of this publication are obtainable only from the Ministry of Natural Resources, Fast Growing Hardwoods Group, Eastern Region, P.O. Box 605, Oxford Avenue, Brockville, Ontario K6V 5V8. Telephone (long distance) (613) 342-8524.

ACKNOWLEDGEMENTS

This project has been jointly funded over the past five years by the Province of Ontario and the Government of Canada under the Canada/Ontario Community and Rural Resource Development Subsidiary Agreement. This agreement, signed in June 1978 by the Minister of Regional Economic Expansion (Canada) and the Treasurer of Ontario, has made possible this innovative project on intensive forest management.

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PREFACE

This publication is a documentation of seven years of soils technology development efforts by the Fast Growing Hardwoods group of Eastern Ontario Region. The intensive soils survey practices and procedures are both unique and timely: unique in being the most intensive operational forest soil survey program in North America at present; timely in the sense of using detailed objective soils information to temper forest management practices.

Since 1978, Eastern Region have organized and hosted several soils workshops and seminars for government and corporate staff. Through these soils workshops, the knowledge of and application of soils information to forest management has evolved. This document will not only facilitate the intensive soil survey of fast growing hardwood production sites, but also demonstrates an approach for objectively assessing potential and existing forest sites for any forest tree species in the Province.

The publication is written in three distinct sections. Chapter 1 "Soils: The Forest Foundation" outlines the evolution of the soils technology which has been developed since 1977 and provides the scientific basis for much of the criteria and procedures which have been adopted in the soil survey. Chapter 2 "Soils and Clonal Growth" provides documentation of more refined techniques to quantify clonal growth in relation to soil characteristics. Chapter 3 "Soil Survey Standards", in conjunction with the legal contract presented in Appendix I, provides the technical and administrative basis to conduct an intensive soil survey as developed and practiced in eastern Ontario since 1977. This contract and technical soils standards were privatized for the first time in 1983, with very favourable results.

Reed (1978) outlines the parameters for intensification of forest management: use of quality genetic stock; identification and use of the better sites; application of advanced cultural practices; practice forestry close to processing mill. The Fast Growing Hardwoods program is a working example of these ideals. The technology herewith provides the foundation for new forests in Ontario.

B.A. Barkley
Forestry Specialist

Soils: The Forest Foundation

SOILS: THE FOREST FOUNDATION[1]/

Soils form the forest base and the integrity of future stands is dependent upon how well this base is identified and managed. Failure to take the variability of soils into account has traditionally resulted in major errors in silvicultural judgement in the choice of species and treatments when plantations have been established.

An intensive soil survey is essential, therefore, for the successful establishment and management of a fast growing hardwood plantation, since it provides for stratification of the land base on which plantations are to be established.

The Land Base

The soils of eastern Ontario are extremely heterogeneous. Three separate periods of glaciation have had a major impact upon the surficial geology of the area. Following the last period of glaciation, the Champlain Sea temporarily submerged portions of the region. The present soils have developed on a variety of materials ranging from fine marine clay to unsorted glacial tills. It is not uncommon to find several different geologic materials present within a single soil profile. Limestone bedrock predominates throughout most of the area, although the acidic Precambrian Shield is present in the central and northern areas. The topography is generally flat to gently rolling. Since the South Nation River, a major drainage system, falls only an average of 45 centimetres per kilometre, drainage tends to be slow and restricted in many areas. The physiography of the area is reviewed in greater detail by Chapman and Putnam (1966). Major features are shown in Figure 1-1.

Settlement and Land Use

Eastern Ontario was one of the first areas to be settled in the province. A detailed land survey was carried out in the late eighteenth century and land was granted in lots varying from 40 to 80 hectares to incoming United Empire Loyalists and other pioneer immigrants.

By the mid-nineteenth century an elaborate network of roads was well established and much of the natural forest was cleared to make way for agriculture. The forest cover in several counties was reduced to less than eight per cent of the total land area.

[1]/ This paper has been adapted from Barkley et al (1983).

Dramatic changes in agricultural technology over the past few decades have had a major impact on land use. As farming operations became more intensive, many parcels of land were considered to be of marginal value for agriculture. Variable soil types, soil drainage problems and excessive stoniness adversely affected farm operations and crop yields. Many areas unprofitable for farming are currently idle, producing no worthwhile crop. It is on these areas that fast growing hardwoods plantations are being established.

Early Observations on Plantation Growth and Soils

In the early stages of the fast growing hardwoods program, the results observed in young plantations were extremely variable. Early practice consisted of planting a single clone over large areas regardless of differences in site. On many of these areas major differences in tree growth often were later associated with variation in soil types.

A number of plantations were established between 1972 and 1975 before the sensitivity of clones to different sites were fully recognized. These have enabled the documentation of differences in growth of a single clone Populus euramericana cv 'I-45/51', on several different soils (Table 1-1). Although the ages vary, the same establishment and tending procedures were used in all examples. The sites were ploughed and disced the year prior to planting. Planting was done in early spring of the next year using 25-cm long unrooted cuttings. Mechanical cultivation maintained weed control during the first three years. The following are brief descriptions of the soils on which the plantations in Table 1-1 were established (detailed descriptions are in Table 1-2).

Johnson North

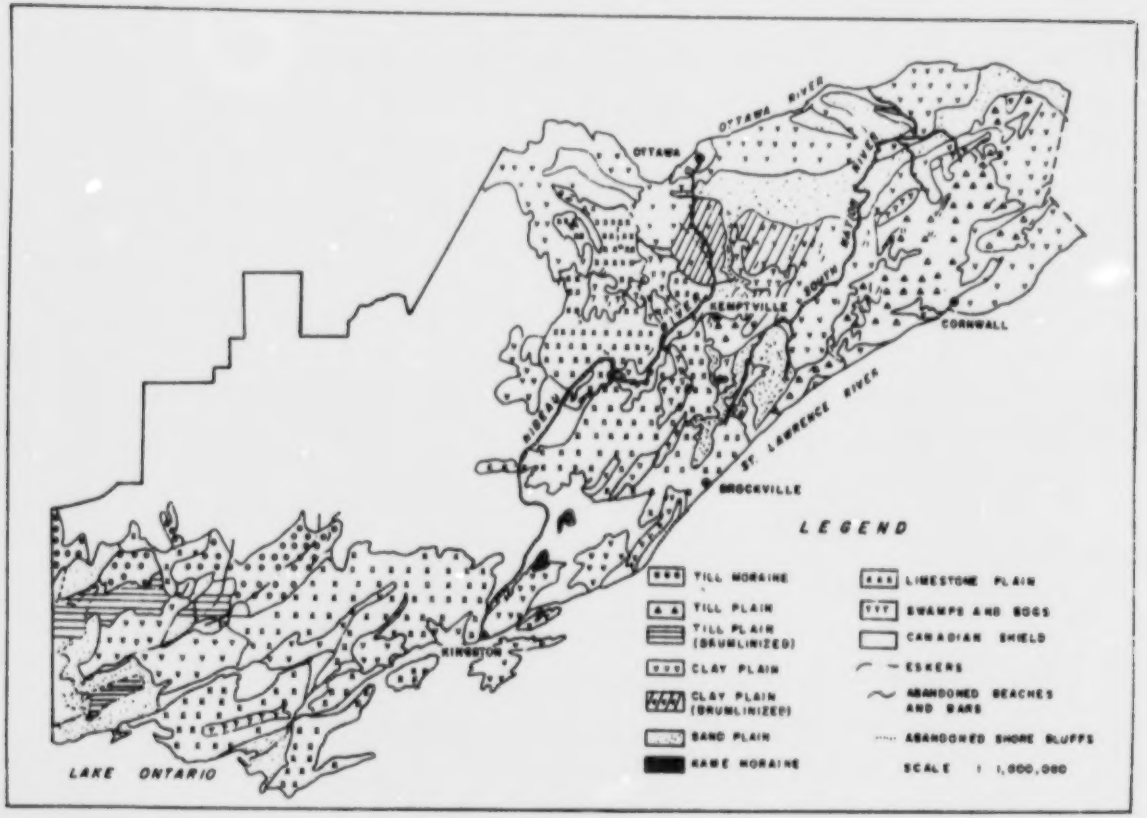
The soils of the Johnson North plantation are imperfectly drained loam over gravelly silt loam ranging from neutral to strongly alkaline with increasing depth. Root development occurs well below the 50 cm depth. This fine textured soil is well structured and slightly compact in the lower profile.

SNA 56

The soil of the SNA 56 plantation is a poorly drained sandy loam over fine loamy sand soil that is acidic and without structure. The profile development is shallow. The light colour of the Ap horizon indicates an organic matter content of less than one per cent. Root development is limited to the upper 20 cm of the profile.

FIGURE 1-1:

MAJOR PHYSIOGRAPHIC FEATURES OF EASTERN ONTARIO



Source: Chapman and Putman, 1966

TABLE 1-1:

PLANTATIONS OF CLONE 'I-45/51' ESTABLISHED ON CONTRASTING SITES. HEIGHTS AND DIAMETERS AS OF DECEMBER, 1982.

Plantation	Location	Year Established	Initial Density Trees per Hectare	Percent Survival in 1982	Average Height (m)	Mean Annual Height Growth (m)	Average Diameter at Breast Height (cm)
Johnson North	North Augusta	1972	1100	90	12.3	1.12	13.9
SNA 56*	Berwick	1974	1100	------SURVIVAL LIMITED--------			
Codrington	Codrington	1974	750	80	14.1	1.57	19.9
Domtar 1	Avonmore	1975	1100	75	10.7	1.34	11.4

* SNA 56 plantation is included for comparison, although by age 4, very few trees have survived.

Codrington

The soil of the Codrington plantation is an imperfectly drained silt loam with a neutral pH. Soil structure is well developed throughout the profile. The soil profile has developed to a depth of 70 cm but roots are present and well distributed at depths below 70 cm. There are no coarse fragments present in the profile.

Domtar 1

The soil of the Domtar 1 plantation is an imperfectly drained loam over silty clay with a neutral pH. The soil horizons are well structured and compact. Root development is limited to the upper 35 cm of the profile. The number and size of coarse fragments increases with depth.

Growth has varied considerably from site to site. On SNA 56 many of the trees were dead by age four. The low vigour of the trees growing on this site resulted in severe damage by Cytospera chrysoperma (Pers) Fr. and Dothichiza populea Sacc. et Br. These two diseases are associated with many hybrid poplar clones growing under stress (Hubbes, 1977; Zsuffa, 1975). The surviving growth on this site consists primarily of coppice sprouts growing from the base of trees with dead tops. The Codrington plantation has always grown vigorously and remained free of insects and diseases. The Johnson North and Domtar 1 plantations have had minor leaf disease problems e.g. Marssonina brunea (E. and E.) Sacc.

Distinct patterns of height growth are associated with the different sites. Cumulative height growth is shown in Figure 1-2. Although the Codrington plantation is two years younger, its trees are taller than those of the Johnson North plantation. The height of the trees at Codrington has been greater than either those at Johnson North or Domtar 1 every year since year two. A comparison of the patterns of annual height growth (Figure 1-3) of the surviving plantations shows growth differences between sites. All plantations grew to approximately the same height in year one. In succeeding years, differences in growth became apparent. The growth rate at Codrington accelerated rapidly and consistently until 1978. The Johnson North growth rate began to accelerate slightly, with considerable fluctuations, starting in 1977. The Domtar 1 growth rate remained relatively slow and consistent until 1981 when it began to accelerate. The similarities between the soil of Domtar 1 and Johnson North (i.e., compacted lower soil profile), may explain the similarities in growth patterns between the two properties, consisting of a relatively slow growth rate in the first five years, followed by a rapid acceleration in growth.

TABLE 1-2:

DETAILED SOILS DESCRIPTION

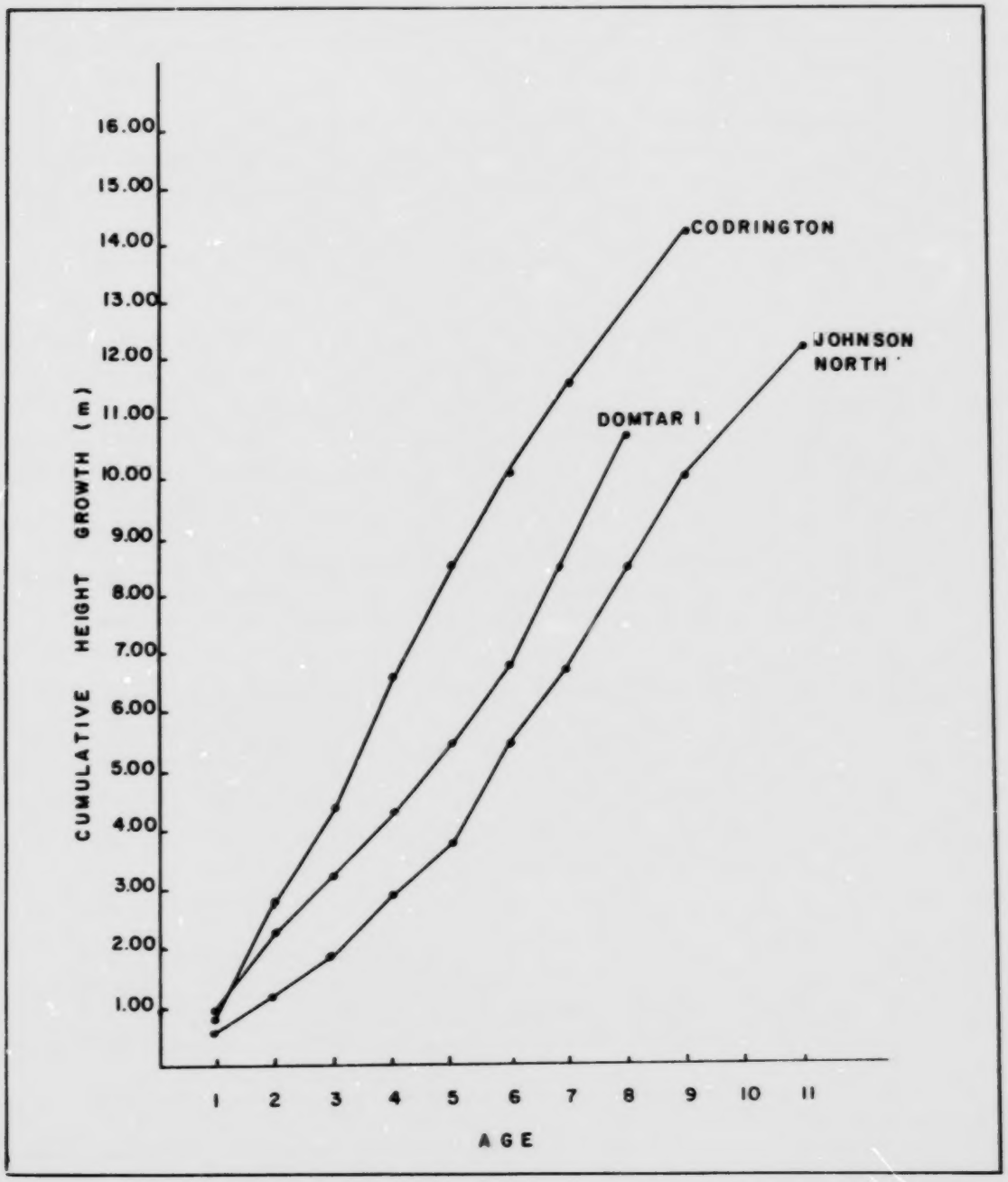
Description	JOHNSON NORTH			SNA 56		
Horizon	Ap	Bt	Ck	Ap	Bfg	C
Depth (cm)	0 - 18	18 - 49	49 - 100	0 - 13	13 - 21	21+
Colour (Wet)	10 YR 3/2	10 YR 3/4	2.5 YR 4/2	10 YR 3/2	10 YR 5/4	2.5YR 5/6
	Very Dark Grayish Brown	Dark Yellow-ish Brown.	Dark Grayish Brown	Very Dark Grayish Brown	Yellow-Brown	Light Olive Brown
Texture	Loam	Silt Loam	Silt Loam	Sandy Loam	Fine Sandy Loam	Fine Loamy Sand
Mottles	None	Very Few, Fine, Faint	Few, medium distinct.	Few, Indistinct	Common, and prominent	Coarse,
Structure	Weak, Crumbly Fine	Moderate, Blocky, Fine	Sub-Angular Blocky, Fine	----------Amorphous----------		
Consistence: Wet Moist Dry	------Slightly Sticky, and Non-Plastic- ------- Very Friable ---- Friable			Slightly Sticky & Plastic	--Non-sticky & Non-Plastic	----------
				-Very Friable when moist----------		
				-Soft when dry----------		
Roots Abundance	Plentiful	Few	Very Few	Plentiful	Few	None
Size	Fine	Medium	Fine	Medium	Very Fine	
Clay Films		Few Thin	Few Thin			
Concretions						
Free Carbonates			Moderate			
Coarse Fragments		Many Cobbles	Many Cobbles and boulders			
Horizon Boundaries		Abrupt Wavy	Abrupt Wavy		Abrupt Smooth	Gradual Smooth
pH	6.0	7.15	8.05	5.6	5.8	5.7
Drainage	Imperfectly Drained			Poorly Drained		

Table 1-2: (cont'd)

DESCRIPTION	COORINGTON				DONTAR I		
Horizon	Ap	Bt	B-C	C	Ap	B	Ck
Depth (cm)	0-22	22-58	58-70	70+	0 - 16	16 - 35	35+
Colour (Wet)	10YR 3/3 Dark Brown	10YR 5/3 Brown	7.5YR 4/2 Dark Brown	7.5YR 4/4 Dark Brown	10 YR 2/2 Very Dark Brown	5Y 7/2 Light Gray	2.5Y Olive Yellow
Texture	Silt loam	Silt Loam	Silt Loam	Silt Loam	Loam	Silty Clay	Silty Clay
Mottles		Few, Fine Faint	Common,	Medium Faint		Many, Coarse and Distinct	
Structure	Moderate Crumb, Medium	Strong, Sub-ang. Blocky Medium	Strong, Sub-ang. Blocky Coarse	Strong, Sub-ang. Blocky Coarse	Weak, Crumb Fine	Strong, Platey Coarse	Weak, Sub-Angular Blocky Coarse
Consistence	--------- Very Friable-------	Slightly	Sticky & Friable	Plastic	------Slightly sticky---------- and plastic		
	---------	Slightly	Hard----------		Very friable, soft-----		Friable Slightly Hard
Roots Abundance	Abundant	Plentiful	Plentiful	Few	Few	Very Few	None
Size	Medium	Fine	Fine	Fine	Fine	Very Fine	
Clay Films		Discontinuous---------- Thin				Few Thin	Few Thin
Concretions			-Moderately Thick---				
Free Carbonate						Very Weak	Strong
Coarse Fragment					Few Cobbles	Few Cobbles	Cobbles Abundant
Horizon Boundaries	Abrupt Smooth	Diffuse Smooth	Diffuse ----- Smooth		Abrupt Wavy		Diffuse Smooth
pH	6.5	6.6	6.4	6.3	6.3	6.9	7.3
Drainage	Imperfectly Drained				Imperfectly Drained		

FIGURE 1-2:

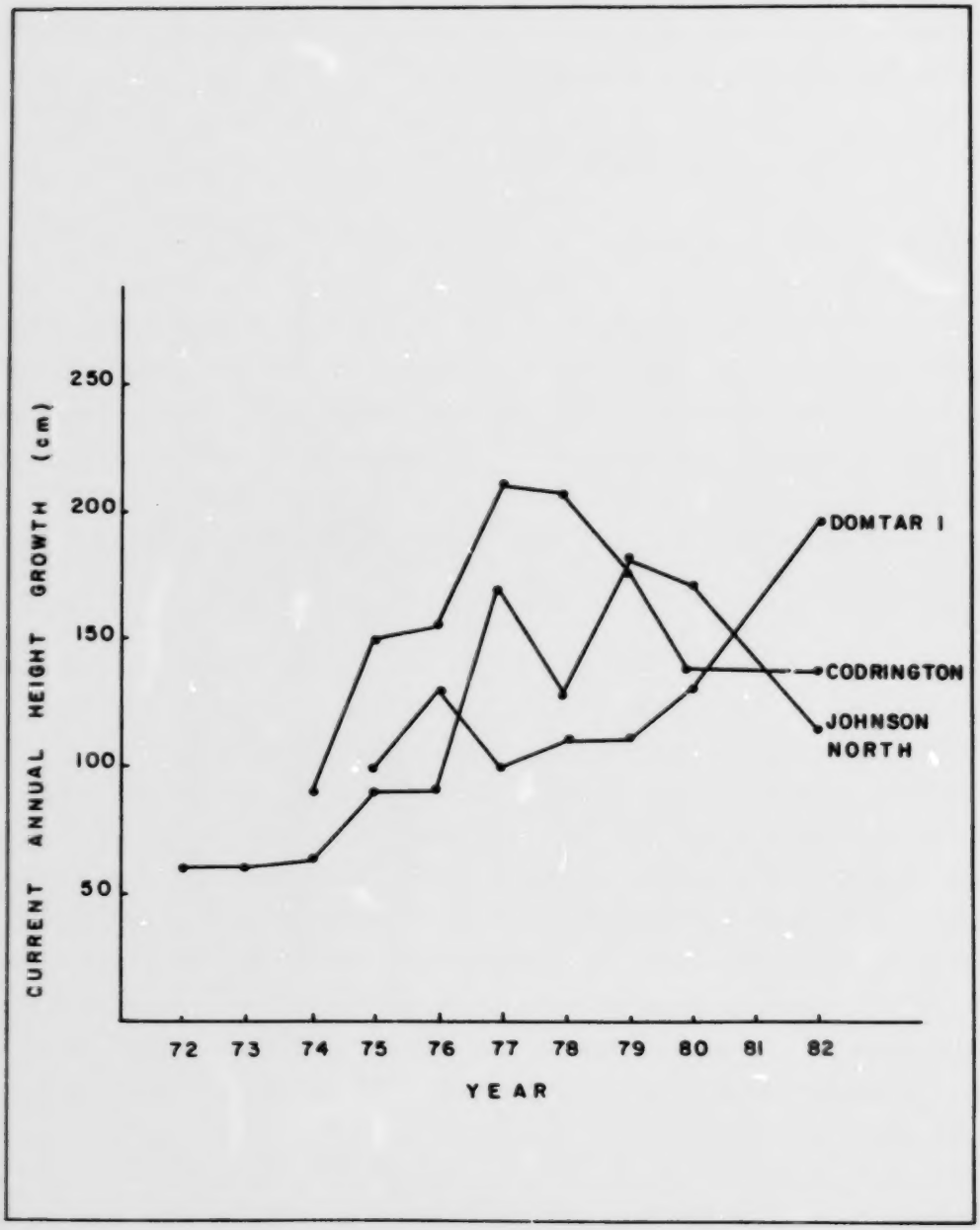
CUMULATIVE HEIGHT GROWTH OF '145/51' GROWING ON THREE DIFFERENT SITES



Note: Data are based on three randomly selected trees on each site

FIGURE 1-3:

CURRENT ANNUAL HEIGHT GROWTH FOR '145/51' GROWING ON THREE DIFFERENT SITES



Note: Data are based on three randomly selected trees on each site

Although based on a very limited sample there are several conclusions which can be drawn from this information. In an eight to ten year rotation, Codrington would be the most productive site; yet in the past four years its rate of growth has significantly declined. This may be a result of the trees having fully exploited the rooting volume of the soil. In contrast, Domtar 1 appears to have a slower rate of rate of growth, but less variation, and represents a situation in which a longer rotation would be necessary to achieve the same results as at Codrington. A more complete analysis of the soils in relation to growth will be given later in this chapter.

SOIL SURVEYS

Development and Selection of Scale

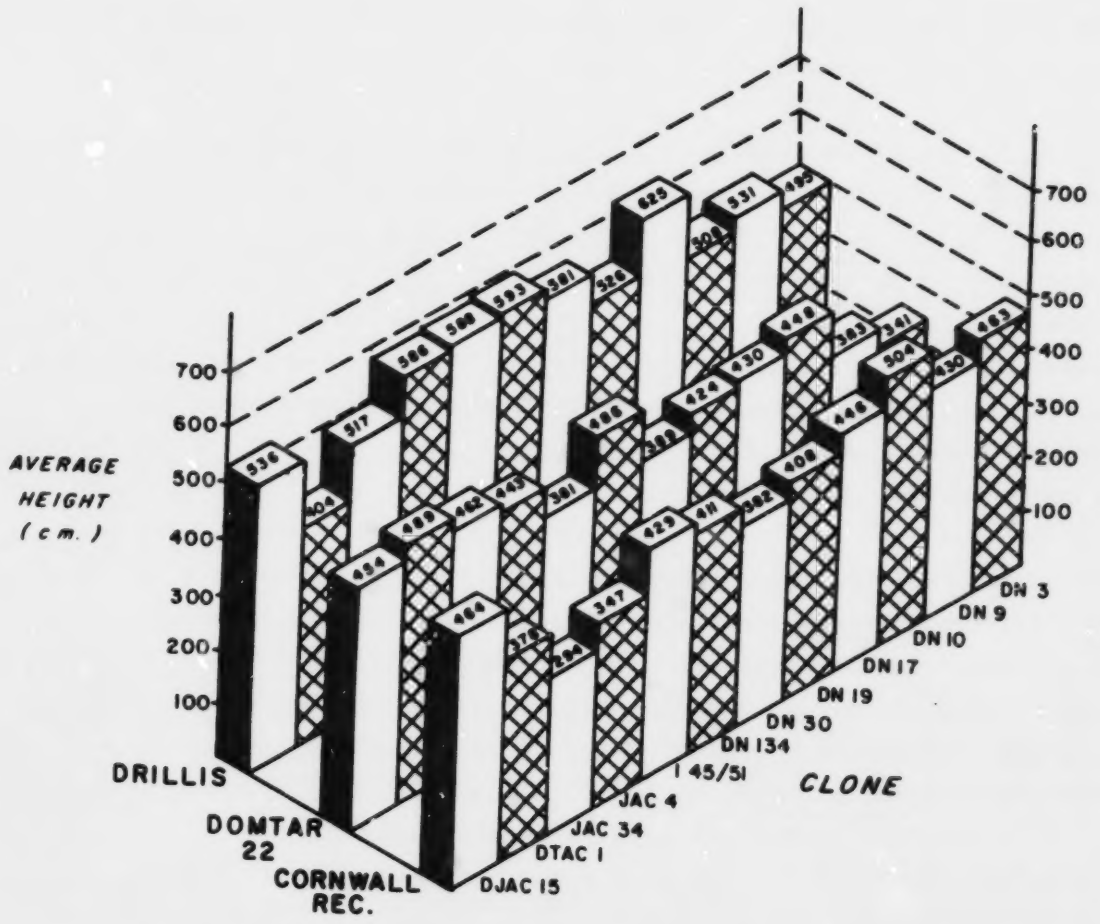
If soil features which affect growth can be identified and mapped, then more effective planning in plantation establishment will result. Soil surveys determine the extent and distribution of various soil types. The scale of the soil survey depends on the intensity of management. Scales as large as 1:2000 may be appropriate for intensive forest management (Armson, 1977). In Ontario, a mapping scale of 1:2000 was selected in view of the following factors:

- This scale is sufficiently large enough to identify the soil variation present over the majority of sites being intensively managed. An area of homogeneous soil type as small as 800 m^2 in size can be identified.
- The allocation of clonal stock to production blocks of uniform soil type is integral to the management of fast growing hardwoods (F.G.H.). The allocation consists of objectively matching the soil characteristics of the production block with a clone-site trial of a similar soil type. The top ranked clones identified from these trials are allocated to the production blocks. The four-year results of three clone site trials are shown in Figure 1-4. The scale of the soil survey in conjunction with the interpretation of the soil variability must allow the identification of clonal blocks 0.5 to 4.0 ha in size.

A preliminary step of the soil survey involves stratifying the area to be surveyed into suitable and unsuitable sites for hybrid poplar plantations.

FIGURE 1-4:

COMPARISON OF AVERAGE HEIGHT GROWTH AT AGE FOUR OF DIFFERENT CLONES ON THREE SITES



Note: Numbers give average height (cm) at age four years

Intensive soil surveys are then carried out on the suitable sites for fast growing hardwoods. Unsuitable sites for fast-growing hardwoods are areas where soil characteristics are at extremes. For example, areas where the bedrock is less than 60 cm below the surface, or the soil consists of excessively well-drained sands, are unable to supply sufficient moisture for hybrid poplar. Also, areas with excessive moisture, such as very poorly drained, fine, massive clay soils, are poorly aerated and limit growth.

Aerial photographs, changes in vegetation and changes in surface relief aid the soil surveyor in delineating the location of the different soil types. Traverse lines at approximately 40 m intervals are made and the soil profiles are systematically examined either using a spade to expose a profile or using a soil auger.

The delineation of different soil types is based upon soil texture, depth, drainage and degree of stoniness. The various soil types are described objectively by examination of the macroscopic features of the soil profile. A detailed profile description (Table 1-3) and the related profile diagram (Figure 1-5) are prepared. A comprehensive and objective soil description provides the opportunity for special interpretations to be made at a later date once the relationship between clones and sites is better understood, thus increasing the usefulness of the soil survey (Armson 1977). The soil profile characteristics are:

Depth The depth of a soil horizon, particularly the A and B horizons indicate the effective soil rooting zone as well as providing an indication of previous land use and vegetative cover prior to management.

Colour Soil colour is an indicator of geological origin, degree of weathering of the soil material, soil moisture degree of oxidation and reduction, organic matter content and leaching or accumulation of such chemical compounds as iron, which may greatly influence site quality (Pritchett, 1973).

Texture Texture determines water retention and movement, aeration and certain aspects of soil fertility (Armson, 1977).

Structure The structure of a soil affects water movement, aeration, bulk density and porosity (Pritchett, 1973).

Consistence Consistence is important in determining the appropriate technique of soil cultivation, as it indicates the ability of a soil to withstand applied stress (Pritchett, 1973).

TABLE 1-3:

EXAMPLE OF SOIL PROFILE DESCRIPTION FOR JOHNSON NORTH

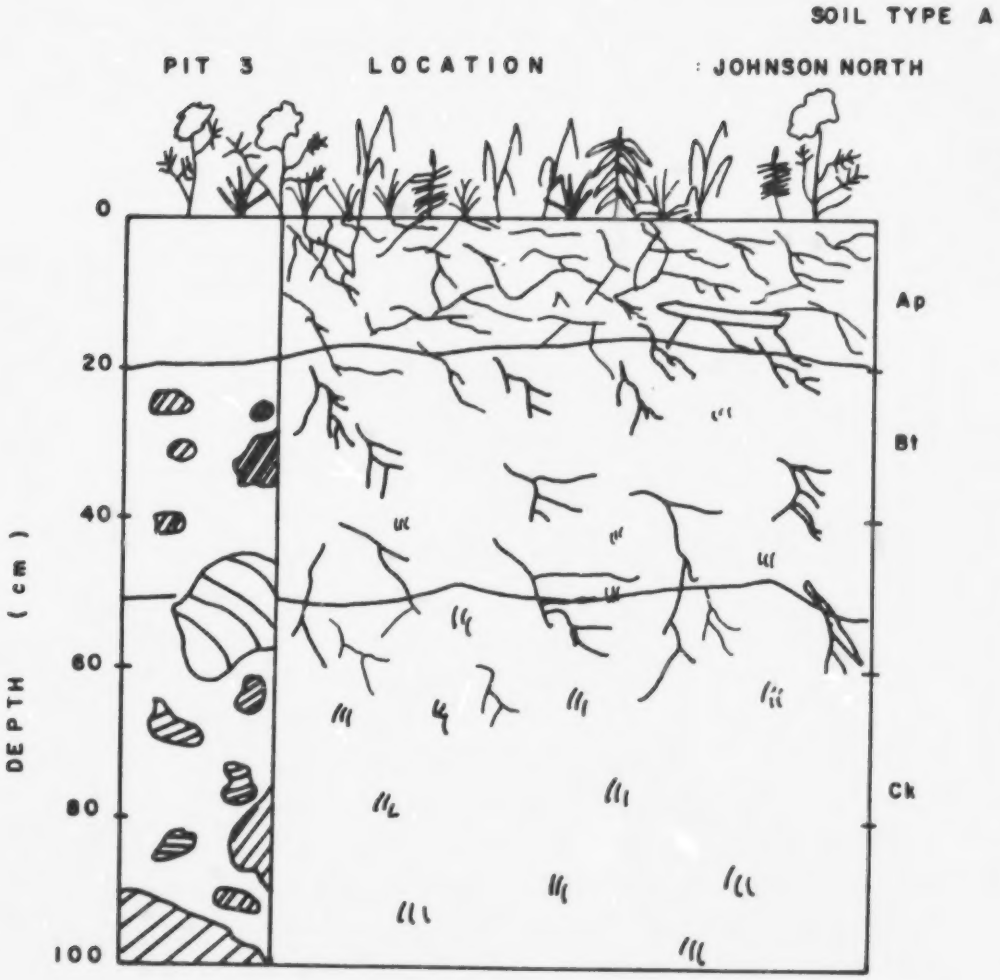
LOCATION: JOHNSON NORTH - NORTH AUGUSTA

PIT 3 **SOIL TYPE: A**

HORIZON		Ap	Bt	Ck		
DEPTH (cm)		0 – 18	18 – 50	50 – 100		
BOUNDARIES	WIDTH	Clear	Clear			
	TOPOGRAPHY	Smooth	Wavy			
COLOUR-MOIST		10 YR 3/2 Very Dark Grey Brown	10 YR 3/4 Dark Yellow Brown	2.5 YR 4/2 Dark Gray Brown		
TEXTURE		Loam	Silt Loam	Silt Loam		
STRUCTURE	GRADE	Weak	Moderate	Moderate		
	KIND	Crumb	Sub-Ang Blocky	Sub-Ang Blocky		
	CLASS	—	Fine	Fine		
CONSISTENCE	STICKINESS	Slightly sticky	Slightly sticky	Slightly sticky		
	PLASTICITY	Non-plastic	Non-plastic	Non-plastic		
	MOIST	Very friable	Very friable	Very friable		
CEMENTATION		—	—	Weak		
DRAINAGE CLASS : Imperfectly Drained						
MOTTLES	ABUNDANCE	—	Very Few	Few		
	SIZE	—	Fine	Medium		
	CONTRAST	—	Faint	Distinct		
ROOTS	ABUNDANCE	Plentiful	Few	Very Few		
	DIAMETER	Fine	Medium	Fine		
	ORIENTATION	Horizontal	Horizontal	Oblique		
	DISTRIBUTION	Inped	Inped	Exped		
	SPECIES	Herbaceous	Woody	Woody		
PORES	ABUNDANCE	Plentiful	Plentiful	Few		
	DIAMETER	Fine	Fine	Micro		
FREE CARBONATES		—	—	Moderate		
COARSE FRAGMENTS	NAME	—	Cobbly	Bouldery Cobbly		
	ABUNDANCE	—	Many	Many		
pH		6.0	7.15	8.05		

FIGURE 1-5

PROFILE DIAGRAM TO ACCOMPANY SOIL PROFILE DESCRIPTION IN TABLE 1-3



REMARKS :

- COMPACT SOIL BELOW 40 cm DEPTH
- NO ROOTS EVIDENT BELOW 80cm DEPTH

Mottles The presence and degree of development of mottles is normally taken as evidence of partial or seasonal conditions of poor aeration (Armson, 1977).
Roots The abundance and size of roots occurring in a soil profile can be used to indicate site productivity and the potential of a soil for root exploitation (Armson, 1977).
Cementations The presence of a cemented layer may impede drainage and root development and thus, indicate the need for further ameliorative operations.
Soil Reaction-pH pH affects availability of nutrients to the plant and the abundance of soil organisms conducive to plant growth (Armson, 1977).
Coarse Fragments The degree of stoniness primarily affects soil moisture movement and root penetration.

Agricultural soil surveys, which have been carried out for most of southern Ontario, are of limited value for the Fast Growing Hardwoods program. The commonly used scale of 1:63,360 is a more suitable scale for planning on a regional basis. Figure 1-6 shows a portion of the agricultural soil survey for Grenville County (Richards and Matthews, 1944) and can be compared with the intensive soil survey map for Johnson North (Figure 1-7). Associated with the major difference in scale of mapping, there is a considerable discrepancy between the mapping units on the two surveys. Also, agricultural soil surveys are generally based on the soil variations that occur in the cultivated plow layer (0-18 cm) rather than the entire profile. As Armson (1977) points out, "Undoubtedly, textural differences within the solum are important, but whether (or not) the arbitrary setting of a surface 15-18 cm in depth for their delineation is justifiable for a soil survey of land whose uses may be largely non-agricultural, is debatable." A forest crop is established for a rotation of several years, during which time the root system will have fully exploited the available soil rooting volume, well below the plow layer.

Interpretation of Soil Survey Results

The rapid production of large quantities of biomass requires large amounts of water and an adequate supply of nutrients. It is possible to make some interpretation of the suitability of a soil to meet these requirements using soil survey results.

The shallow profile development, major gleyzation, and the poorly drained nature of the SNA 56 soil severely limits the volume of the soil available for

FIGURE 1-6:

SOILS OF THE JOHNSON NORTH PLANTATION AS DELINEATED BY AGRICULTURAL SOIL SURVEY

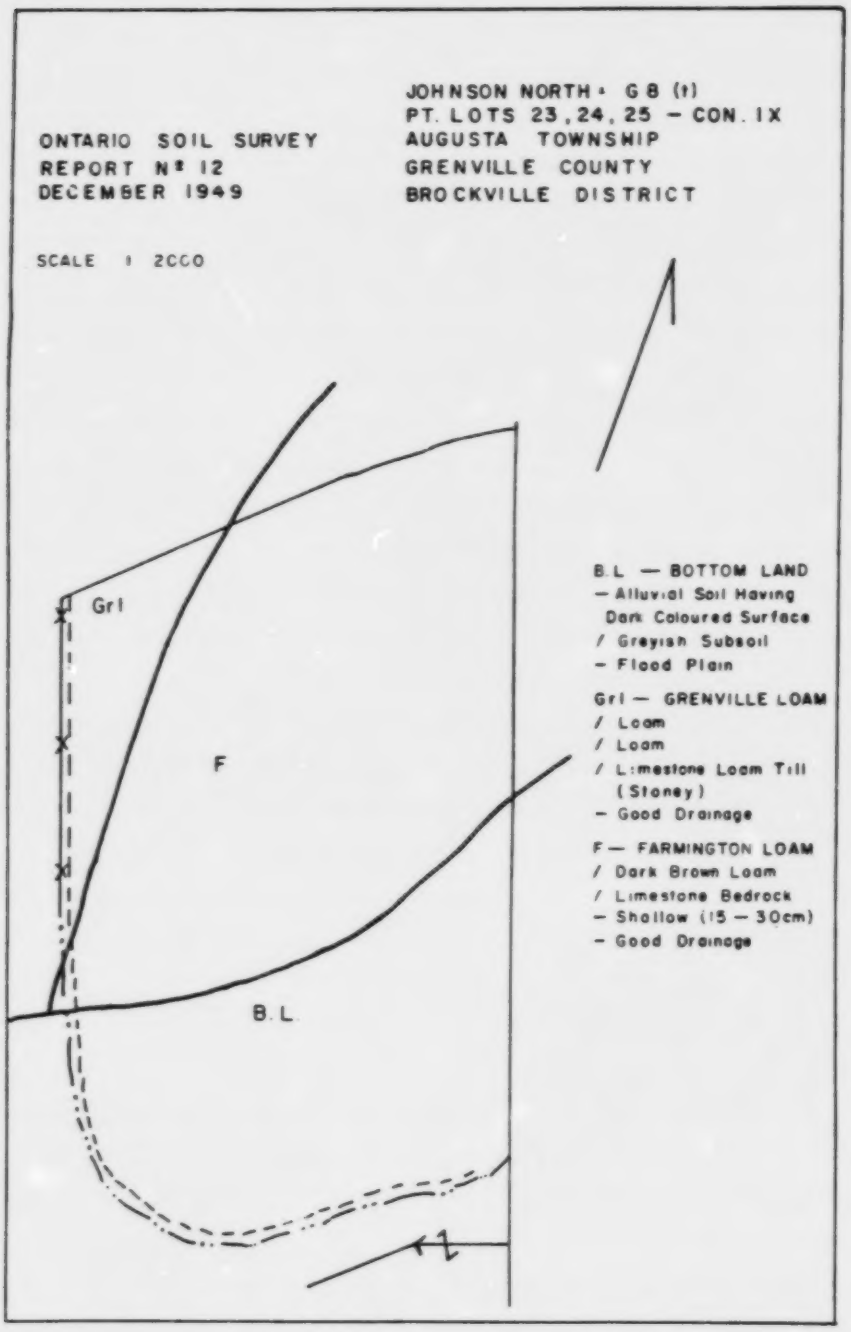
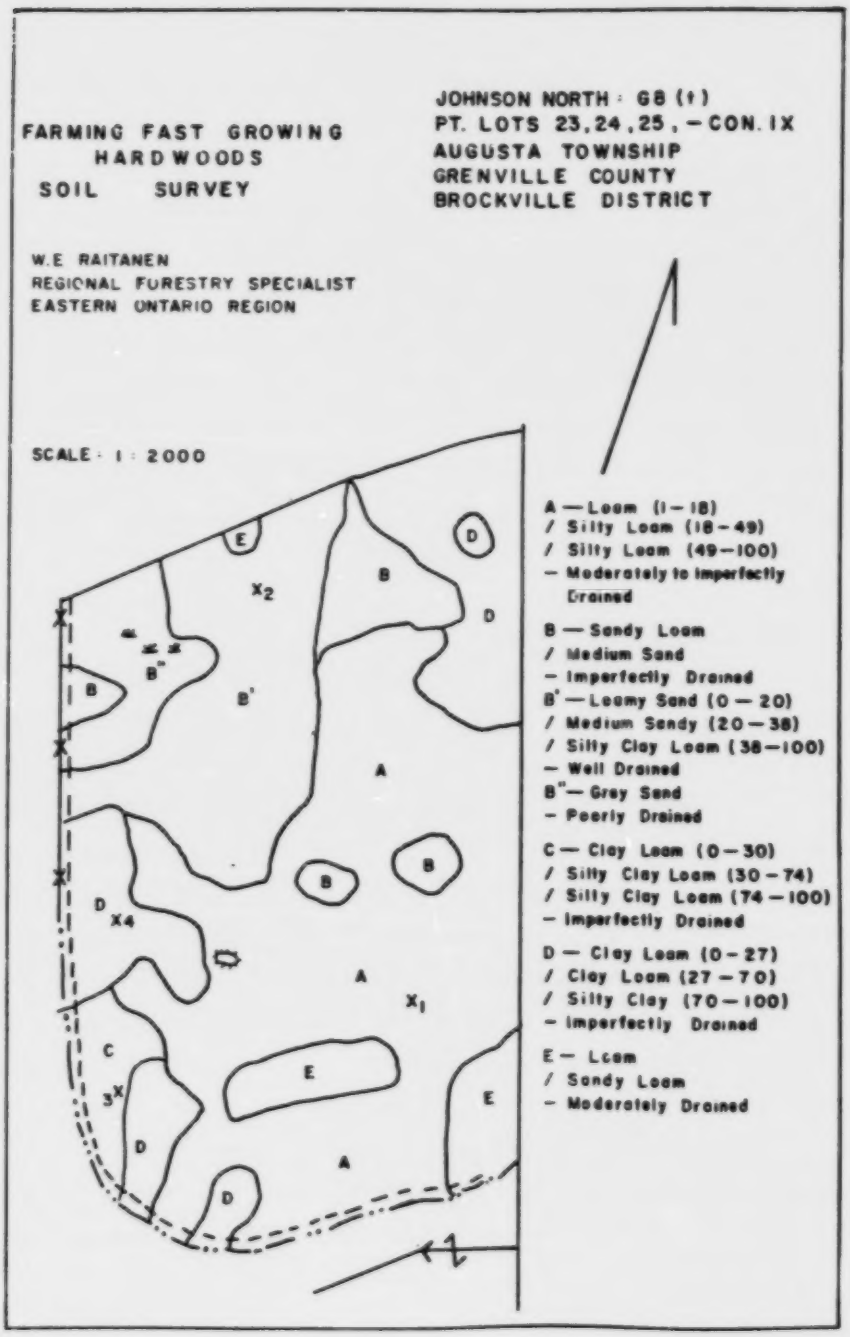


FIGURE 1-7:

SOILS OF JOHNSON NORTH PLANTATION

AS DELINEATED BY INTENSIVE SOIL SURVEY


FARMING FAST GROWING
HARDWOODS
SOIL SURVEY
W.E RAITANEN
REGIONAL FORESTRY SPECIALIST
EASTERN ONTARIO REGION
JOHNSON NORTH : G8 (1)
PT. LOTS 23,24,25, - CON. IX
AUGUSTA TOWNSHIP
GRENVILLE COUNTY
BROCKVILLE DISTRICT
SCALE : 1 : 2000
A — Loam (1 - 18)
/ Silty Loam (18 - 49)
/ Silty Loam (49 - 100)
- Moderately to Imperfectly Drained
B — Sandy Loam
/ Medium Sand
- Imperfectly Drained
B' — Loamy Sand (0 - 20)
/ Medium Sandy (20 - 38)
/ Silty Clay Loam (38 - 100)
- Well Drained
B" — Grey Sand
- Poorly Drained
C — Clay Loam (0 - 30)
/ Silty Clay Loam (30 - 74)
/ Silty Clay Loam (74 - 100)
- Imperfectly Drained
D — Clay Loam (0 - 27)
/ Clay Loam (27 - 70)
/ Silty Clay (70 - 100)
- Imperfectly Drained
E — Loam
/ Sandy Loam
- Moderately Drained

rooting. Roots are confined to the upper 25 cm of soil. The acidic pH (5.7) observed in this soil has been associated with other failures of Populus euramericana cv plantations in eastern Ontario.

Domtar 1 is typical of many imperfectly drained sites in eastern Ontario. The soil is fine textured but well structured facilitating aeration. The compact lower portion of the soil profile slightly impedes root growth. The neutral to slightly alkaline pH is favourable for nutrient availability. The volume of soil available for root growth will be somewhat restricted until the roots are able to penetrate the compact lower soil profile. The water supply and nutrient levels appear to be adequate.

The imperfectly drained, medium to fine textured soil of Johnson North provides a good growing medium. However, the very compact lower soil profile impedes deep root development. Root growth will be initially restricted on this site until the compact lower soil is penetrated. The highly alkaline soil indicates an abundant supply of calcium.

The imperfectly drained, fine textured soil at Codrington provides for high rates of growth; the well structured soil aids aeration and ease of root penetration to a great depth. In a fine textured soil of this nature, the fertility levels can be expected to be high.

An Operational Soil Survey

As the area of plantings increases from less than 500 hectares per year to 1,000 hectares per year or higher, certain aspects of the soil survey will require modification. The present unit cost for the soil survey which includes preliminary stratification, mapping, pit excavation and a detailed profile description with pH analysis is $50 per hectare. A target cost of $25 per hectare should be attainable. Various cost reductions and increased operational efficiencies can be realized by using special techniques such as supplementary aerial photography to prestratify the soil survey area.

The primary function of a soil survey as described by Armson (1977) is to "provide objectively determined quantitative and qualitative information about soils and their distributions in a given area. It may also provide certain interpretive information in relation to various uses but it should not do this at the expense of basic soil survey information." A sound soil survey, once completed, will provide the basis for a wide variety of future interpretations, at no additional cost to the forest estate.

Soils: The Basis for Investment Decisions

Accurate soils information is important in many management decisions and in scheduling day to day operations. The development of site preparation prescription for a site depends on interpreting many soil characteristics such as drainage, texture, consistency and stoniness. The type and amount of herbicide required for an area is partially governed by soil texture. Texture also strongly affects the behaviour of the chemical residue. Poorly drained areas may be greatly improved by constructing drainage ditches. Soils with serious fertility problems may require a detailed soil analysis and special amelioration treatments. Poorer land may require additional inputs over those required for better quality sites. This may result in a reduced return on the investment, unless the costs of the additional inputs are balanced by a lower land cost. The most important use of the soils information is in the selection of the most appropriate genetic materials for planting on a given site. The appropriate stock is required if the full productive potential of the site is to be realized. Implicit in this selection process is an understanding of the relationship between soils and the growth of different species and cultivars.

Soils and Clonal Growth

SOILS AND CLONAL GROWTH

A Technique for Quantifying This Relationship for Fast Growing Hardwoods

INTRODUCTION

The growth and yield of fast growing hardwoods can vary significantly with site quality. Accordingly, intensive management of forest land requires the determination of the productive capacity or site quality of the land for several alternate tree species. Comparisons can then be made of the predicted yields and values so that the most productive and valued tree species can be selected for each parcel of land. Using this information, a forest manager can estimate future wood supplies, and thus can make realistic decisions about future expenses and profits associated with intensive forest management, land acquisition and industrial investments (Carmean, 1975).

This three step process - identifying suitable sites, matching the most appropriate clone, and predicting yield or return - parallels developments within the Fast Growing Hardwoods program. Site quality is strongly associated with those soil features that determine the quantity and quality of growing space for tree roots (Carmean, 1970). Thus, the first step towards accurately estimating yield is a thorough description of all soils characteristics of possible significance to tree growth. Intensive soil survey standards have been developed by the Fast Growing Hardwoods program in order to achieve this goal of collecting complete and accurate soils data in a relatively objective and quantitative manner.

Secondly, growth response to soil characteristics must be explored and determined in order to effect the best match of genetic stock to soil conditions. This study is directed towards this (longer term) goal. In addition to establishing the presence of definite soils-growth relationships, some specific information is presented for one clonal-age-soils combination.

The third step in this process is the use of information generated from the previous two steps to predict the yield expected from a given site-species combination. This information will be invaluable in best managing available resources and reducing risk for the forest manager.

METHODOLOGY

DESCRIPTION OF DATA

A. Independent Variables - In this study soils variables were those contained in the intensive soil survey standards (see Figure 2-1). Thirty- three variables were described for each of four horizons - A_1, B_1, B_2 and C_1 - for each case or soils pit. The description was limited to four horizons as over 90% of these pits were described in terms of these (or fewer) horizons only. The variables were primarily physical characteristics including soil depth, colour, texture, and stoniness for a soil pit face measuring one square meter. An explanation of how these variables were described is given in a later paper (Soil Survey Standards). Two hundred soils pits were included in this study, spanning the range of soils typical of hybrid poplar sites in eastern Ontario. Levels of measurement varied from nominal to interval level, but were mainly at the ordinal or interval level.

One assumption in this study was that soils variables are invariant with time. As the soils data base was collected over a five year period, certain physical properties may have changed during that time which may have affected correlation with growth data.

Soils pits corresponding with growth data were located within 15 m x 15 m plots within clone site trials.

B. Dependent Variables - The growth data were selected using strict criteria which limited the growth data to correspondence with 38 soil pit descriptions. This was necessary in order to ensure that growth differences could be related and attributed to changes in soil characteristics, rather than some other variables outside the scope of this study. Data were derived from previously established clone site trials which were a minimum of three years old. The inter-tree spacing was 3m x 3m in all trials. Each trial selected had a history of good weed control and was without any abrupt changes in topography.

FIGURE 2-1:
SUMMARY OF SOILS VARIABLES

DEPTH	- of each horizon
COLOUR WET	- hue
	- value
	- chroma
MOIST	- hue
	- value
	- chroma
TEXTURE	
STRUCTURE	- grade
	- kind
	- class
CONSISTENCE	- stickiness
	- plasticity
	- moist
PORES	- abundance
	- diameter
MOTTLES	- abundance
	- size
	- contrast
ROOTS	- abundance
	- diameters
	- orientation
	- distribution
	- species
CEMENTATION	
CONCRETIONS	
CLAY FILMS	
COARSE FRAGMENTS	- abundance
	- size
FREE CARBONATES	
pH	
BOUNDARY	- width
	- topography

Note: Variables were described for each of 4 horizons.

Two clones were chosen, both having been used extensively in the Fast Growing Hardwoods Program: 'DN 17' - a Populus euramericana clone originating in France, and 'I-45/51' - a P. euramericana clone from Italy. Expressions of response were usually based on 25-tree plots (in a few cases there were only 16 trees/plot). Average height was calculated on a per plot basis, by dividing the sum of all tree heights in the plot by the number of living trees. Data were included from both three and four years of age. Diameter at four years of age was not considered to be large enough to be a significant response variable.

ANALYSIS

Analyses were performed using SPSS programs (Nie et al., 1975). Basic statistics were first generated for both the dependent and independent variables in order to explore their variability and distribution. Several new variables were created from the input variables eg. width of B horizon, depth at which first fine textured soil was found, depth to (abundant) mottling, and depth to the C horizon. Some nominal level variables were dropped at this stage due to lack of variability.

Relationships between individual soils characteristics were explored using contingency tables and chi square statistics.

Reduction of the number of independent (soils) variables was required due to the relatively small dependent (growth) data set. This was accomplished through the use of principal component analysis, the method of factoring being principal factoring without iteration. Each horizon was considered separately: the method of selection was Jolliffe's (1972) "B1" method. Factors were dropped if their associated eigenvalues were less than 20% of the highest eigenvalue. One created variable, depth to the C horizon, was included with the data set for every horizon initially, in order to act as a standard. The end result was the retention of several variables per horizon for use in regression. In each case, the variables retained were those which corresponded most closely with the factors with the highest eigenvalues.

Simple linear regression was used to determine relationships between the dependent variables of average height at three and four years of age for both clones, and soils variables. Relationships were considered significant when $|r| \geq 0.50$ (the Pearson product-moment correlation) and the significance of $r \leq .05$.

Step-wise multiple regression techniques were applied to explore the linear relationships between significant soils characteristics and average height growth at three years of age for 'DN 17'. Data for clone 'I-45/51' were not used as dependent variables in this procedure as there was a lesser amount of data available for this clone than for 'DN 17', thereby weakening the significance which could be attached to the outcome. Fourth year average height growth was excluded at this point as it constituted a smaller data base than third year height growth. Soils characteristics were considered significant if they were one of the remaining variables after principal component analysis, or if they had been found to be significantly related to dependent variables by simple linear regression. An initial set of six regressor variables was randomly selected from the significant soils variables to commence the regression. After each regression, the last variable to be entered into the regression equation was dropped and a new variable was added, maintaining the number of independent variables at six. This procedure was repeated until all significant soils variables had been included. Variables were retained in the final regression equation if their inclusion increased the R-square value by more than 10 per cent.

RESULTS

The results from the contingency tables comparing soils charactoristics in a pairwise fashion together with information derived from the principal component analysis, are presented in Figure 2-2, a model of interaction between soils variables involved in this study. Models were first constructed independently for each of the four horizons, and then merged to form the general model of soil characteristic interaction shown in Figure 2-2. Thus, only the relationships which were common to all four horizons are presented here. Characteristics which covary strongly and consistently have been assigned to the same box. Lines between boxes indicate positive relationships, unless identified as negative (-). In some cases, a particular relationship is shown as being both positive and negative, indicating that the nature of the relationship was dependent on the horizon. Absence of lines betwen boxes indicates the absence of any detectable relationship.

In Table 2-1 are listed the soils variables remaining after data reduction by principal component analysis. The variables are paired with the factors with which they are most closely associated, the eigenvalues of those factors,

FIGURE 2-2:

SUMMARY OF RELATIONSHIPS AMONG SOILS CHARACTERISTICS

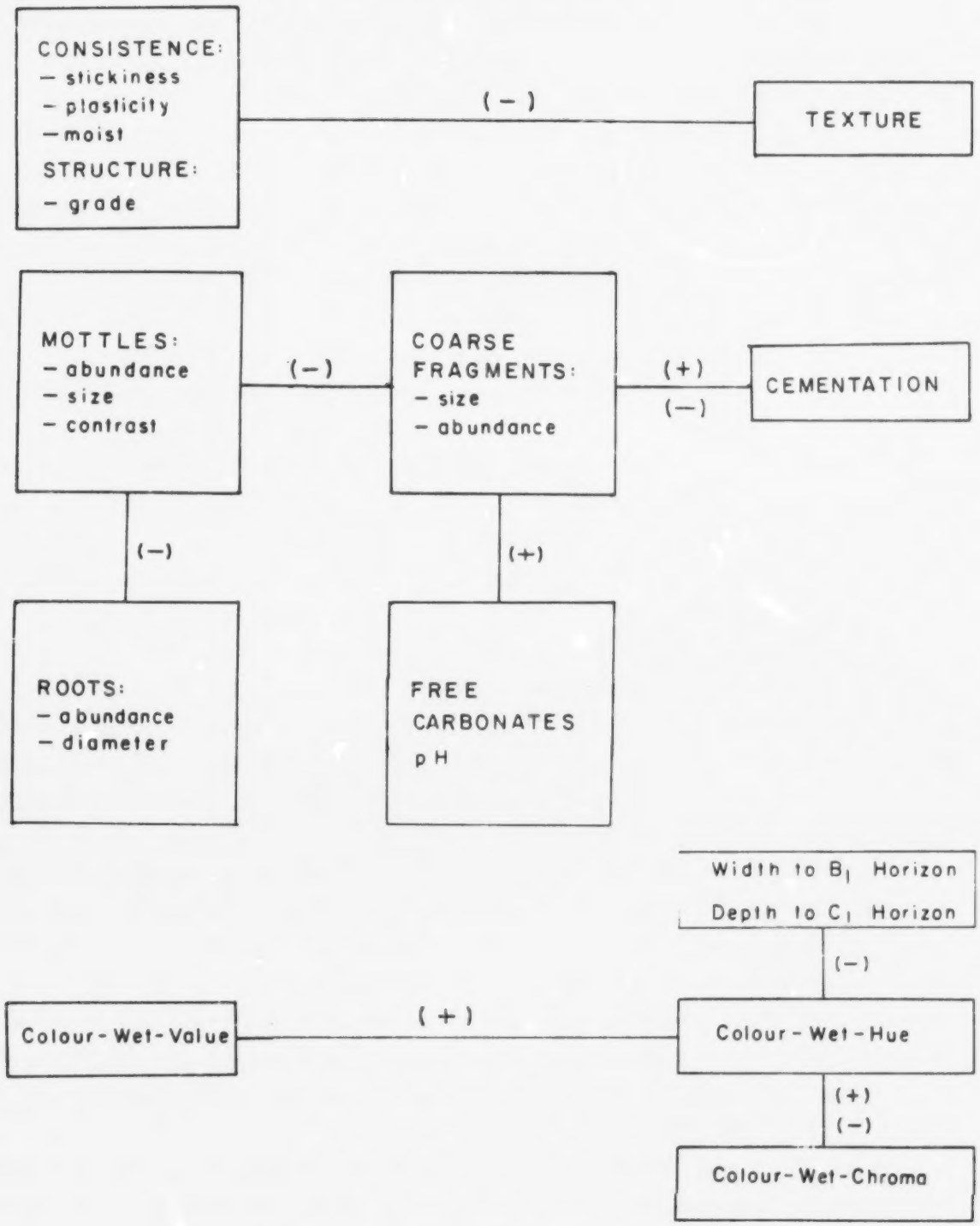


TABLE 2-1:

SUMMARY OF SOILS VARIABLES REMAINING AFTER PRINCIPAL COMPONENT ANALYSIS

Horizon	(Associated) Variable	Factor	Eigenvalue	Percent of Variation
A_1	Free Carbonates	1	1.16	23.3
	Depth to C_1 horizon	2	1.08	21.5
	Concretions	3	.96	19.2
	Roots - Abundance	4	.94	18.8
	Mottles - Size	5	.86	17.2
B_1	Roots - diameter	1	1.32	26.5
	Width of horizon	2	1.07	21.3
	pH	3	.91	18.3
	Colour-Wet-Chroma	4	.89	17.8
	Colour-Wet-Value	5	.81	16.2
B_2	Colour-Wet-Value	1	1.39	27.7
	Cementation	2	1.11	22.1
	Depth to C_1 horizon	3	.97	19.4
	Concretions	4	.84	16.8
	pH	5	.70	13.9
C_1	Cementation	1	1.06	21.2
	Depth to C_1 horizon	2	1.04	20.7
	Colour-Wet-Value	3	.99	19.8
	Mottles-Size	4	.98	19.5
	Depth of horizon	5	.93	18.7

which they are most closely associated, the eigenvalues of those factors, and the percent variation explained by each factor. This is the product of six to eight reductions (ie. factoring procedures) per horizon.

Significant linear relationships between independent (soils) and dependent (growth) variables appear in Table 2-2. Relationships were considered significant if they had an r value greater than 0.50, and the the significance of the F value was .05 or less.

The final multiple regression equation and associated statistics are presented in Table 2-3.

TABLE 2-2

SIGNIFICANT LINEAR RELATIONSHIPS BETWEEN INDEPENDENT (SOILS) AND DEPENDENT (GROWTh) VARIABLES

SOILS VARIABLE

Horizon	Variable	Clone	Age (years)	F	r	r^2
A_1	Colour-wet-value	IN 17	3	.0007	.86	.75
A_1	Texture	IN 17	3	.02	.54	.29
C_1	Roots-Abundance	IN 17	3	.02	.55	.31
A_1	Consistence-stickiness	IN 17	4	.03	.74	.55
B_1	Texture	IN 17	4	.02	-.79	.63
B_1	Roots-abundance	IN 17	4	.05	.63	.40
A_1	Texture	I-45/51	4	.04	-.57	.33
B_1	Mottles-abundance	I-45/51	4	.02	-.65	.42

TABLE 2-3:

SELECTED STATISTICS FROM MULTIPLE REGRESSION

Multiple R	.9558
R^2	.9136
Standard Error	.1969
F	14.10

Independent Variables	B	Beta*
A_1 Colour-Wet-Value	.7142	.7539
A_1 Colour-Wet-Chroma	.3198	.4047
b_1 pH	.1423	.2441
(Constant A)	-.8491	

* Standardized Regression Coefficient

DISCUSSION

Determination of site quality is a prerequisite for intensive forest management. According to Carmean (1975), site index based on height growth and age is the most widely accepted method for estimating site quality. As age and density were controlled in this study and the trees were only four years old, height growth was assumed to be an accurate response variable. Thus, by determining the relationships between soil characteristics and this response variable, it should be possible to select suitable sites for poplar with more precision and to predict yield with more confidence.

The focus of this study is an equation derived from Table 2-3, which relates the average height at three years of age of 'DN 17' (Y) with soils variables whereby,

$$Y = -.85 + .71\ (A_1\ CWV) + .32\ (A_1\ CWC) + .14\ B_1\ pH \qquad r^2=0.91$$

where A_1 CWV = Colour-Wet-Value of the A_1 Horizon

A_1 CWC = Colour-Wet-Chroma of the A_1 Horizon

B_1 pH = pH of the B_1 horizon

The strength of this relationship is indicated by the high r^2 value.

Note that all three of the soils variables are located in the upper two horizons which corresponds with the location of the most intensive rooting zone of a three year old cottonwood-type hybrid (Barkley et al, 1983).

The significance of soil colour is also readily interpreted. Colour of a soil reflects organic matter content and mineral composition (Armson, 1977). In temperate regions of the world, the darkness or lightness in colour of a soil, that is, value, has been used as an index of level of organic content and, by extension, of fertility. In this study average height increased as colour value increased, that is, as soils became lighter. Both Armson (1977) and Shields et al (1968) note an inverse relationship between value and organic matter content for temperate region soils. This relationship has been confirmed for soils in southeastern Ontario (Kelly, 1978). The relationship between value and organic carbon is strongest with high colour values and percent organic matter almost becomes a constant at values less than 4. This is due primarily to the fact that approximately five per cent organic matter is sufficient to coat the inorganic particles and produce the dark colour (Kelly, 1978). As the range of colour value in this study was 2 to 5, indications are

that this inverse relationship does not hold. However, the strong relationship with growth defined by a very narrow range of colour value indicates a high degree of sensitivity to some other meaningful soils characteristic. The significance of value may be more related to soil moisture. Shields et al (1968) reported that the addition of moisture caused the value of Podzolic soils to decrease by 1.5 to 2.0 units. Thus, the positive relationship observed between value and growth may be indicative of a preference by 'DN 17' for drier soils. As the majority of sites included in the study were imperfectly to poorly drained, this indicates that the cottonwood may have been responding to conditions of better drainage and aeration in the surface horizons. Cottonwood can utilize large quantities of water but grows poorly where water is stagnant (Smith, 1957). Better aeration would facilitate tree nutrition by promoting higher rates of decomposition.

The relevance of colour chroma to height growth is not as clear. The notation for chroma consists of numbers beginning at zero for neutral grays and increasing at equal intervals to a maximum of twenty. However, the range for chroma encountered in this study was only from one to five, indicating a very sensitive growth response to changes in chroma. Armson (1977) notes that chroma increases with such additions as humus but that this effect is also very dependent on soil texture. Organic matter tends to make the soil brown to black in colour. The intensity of the colour varies with the quantity of decomposing material and the degree of decomposition which has taken place. If the organic matter is partially decomposed it will give more of a brownish colour, whereas if it is well decomposed and is present as a fine humus, it will usually give the soil a blackish colouration (Armson, 1977). Thus, the increase in height growth with chroma could be a response to increasing levels of humus or organic matter. As the amount of organic matter present in the plow layer of a reforested soil largely determines the quantity of available nitrogen for tree growth (Gilmore and Boggess, 1976), this could be a fertility response.

The pH of soil in the rooting zone can control to some degree the amount of relative availability of nutrient (and other) elements (Armson, 1977). The cottonwood-type hybrid in this study exhibits a positive relationship between growth and pH. The pH of the B_1 horizon ranged from 5.2 to 8.6. Thus, there appears to be a preference for more basic soils, at least within this range. This agrees with the findings of Smith (1957) who reported that black

cottonwoods grow well in soils that are neutral or slightly alkaline but may grow poorly in some soils with a pH below 5.5. He also noted that hybrid poplars used in the Fraser River area are less tolerant of low pH than is black cottonwood. These results are also consistent with those of Bowersox and Ward (1977) who found the pH of the A_p horizon (upper 23 cm) to be significantly correlated with first and fourth year height growth of three Populus hybrids established on an old field site in Pennsylvania.

There are several other relationships discovered between 'DN 17' at four years of age and soils variables, which further elucidate the situation (see Table 2-2). Texture is found to be negatively correlated with height growth, indicating that average height increases as the percent fines in the B_1 horizon increases. This would increase the cation exchange capacity, which would influence the level of fertility. Barkley (1978) cites numerous references where soil texture was found to be strongly correlated with aspen growth. The optimum soil for aspen was a loam with a 50% to 55% silt plus clay content in the A and B horizons. The best sites were thus sandy loams to silt loams, where there were no special soil water conditions existing. As the range of soil textures which were correlated with fourth year height growth of 'DN 17' varied from sandy loam to fine sand, this study agrees with those findings by showing a preference for the sandy loam soils. That stickiness of the A_1 horizon is also strongly correlated with height growth is to be expected due to the strong relationship existing between texture and consistence (see Figure 2-2).

The relationship between weed root abundance prior to site preparation in the B_1 horizon and height growth could be an indication of several conditions which are well suited to plant growth, including adequate nutrition and pore space or bulk density. Plants, especially herbaceous species, would more easily penetrate a soil with low bulk density. Similarly, there is evidence that increasing bulk density can considerably retard the root and shoot growth of planted cottonwood cuttings (Broadfoot and Bonner, 1966).

CONCLUSIONS

Since Coile's (1952) comprehensive review of soils and forest growth, many studies have been directed towards refining this relationship. Baker and Broadfoot (1977) proposed a technique of site evaluation for several major hardwood species which involved weighting and evaluating a number of soil properties that affect tree growth. The advantages of this technique are: (1) it provides accurate estimates of site index under any soil or site condition; (2) it can be applied throughout the southern hardwood region except in those mountainous areas where aspect is important; (3) it does not require identification of soil series; and (4) it provides guidelines for soil ameliorative treatments. However, the technique is limited in that it still requires a certain amount of subjectivity in evaluating the sites and generally does not allow for intraspecific variation. The methodology followed by the present study, which involves uniform spacing and age of clonal stock, and objectively described soils characteristics, presents a technique with all of the advantages of the Baker and Broadfoot method - and more. It is a technique which can yield useful information to the forest manager in determining site acceptability, choosing the most appropriate species and clone, and in providing an indication of future returns for his efforts.

Initially, there is the temptation to use the results of the statistical analysis to reduce the number of data collected in the intensive soil survey. This would be an inappropriate application for several reasons. First, the regressor variables selected through principal component analysis and remaining after multiple regression, are only those which in combination give the most precise estimates of site quality. There may be many soil features which may be associated with site quality in addition to those that appear in the final regression equation (Carmean, 1970). Secondly, the soils variables which have been identified as significant at this point may change with time: the trees in this study were only four years of age. The time element in particular is an important consideration as the growth rate of clones changes with age. In a test plantation established at a 3 m x 3 m spacing in southern Ontario, Zsuffa (1975) found that the ranking of hybrid poplar clones changed considerably during the first six years of plantation age. Thirdly, relationships among individual soil characteristics are related to other environmental conditions such as climate and topography, and may thus vary with geography. Also, only

one clone was used in the final regression analysis: no doubt genetics influence growth-soils relationships. That there is a great deal of inter- and intraspecific variation in Populus species has been frequently documented. One good example of clone site sensitivity is given by Barkley et al (1983) in a comparison of average height growth at age four of 14 different clones on four different sites in south eastern Ontario. There is a good deal of variation both among different clones on one site, and within the same clone among the four different sites. Finally, the soil characteristics which are used to identify major soils types - texture, depth, stoniness and drainage - may not necessarily be the soils characteristics which correspond most closely with tree growth, as found in this study. Thus, many soils variables must be described and considered in order to identify and interpret relationships between the major effector variables - which identify soils type and without doubt influence tree growth - and the indicator variables - which provide a more sensitive indication of growth response.

This study has provided very significant evidence of specific and meaningful growth-soils relationships for a hybrid poplar clone. In the future, volume may take the place of average height as the response variable. Further work is warranted to include other clones and other fast growing tree species, and to continue this and other studies over a longer period of time and in other geographic areas. Studies of this nature would ultimately provide invaluable information to the intensive forest manager in terms of:

- Identifying and assessing suitable sites for fast growing hardwoods production;
- Assisting in allocating the most suitable clone to the site; and
- Predicting the performance of a particular clone on a known site.

Soil Survey Standards

SOIL SURVEY STANDARDS

The development of the intensive soil survey has resulted in the use of a highly refined set of criteria and procedures. These refined standards for mapping, describing and presenting soils information are outlined within this chapter and have been written to be included as the technical appendices specified in a formal soil survey legal contract presented in Appendix I.

The soil survey standards are presented under three major categories:

1) Soil Survey mapping requirements
2) Soil profile description criteria
3) Final soil survey report

SOIL SURVEY MAPPING REQUIREMENTS

Intensive soil survey involves the identification and delineation of soil types on the basis of differences in specific soil parameters. Sampling intensity must ensure that a soil type encompassing an area of at least 800 square meters would be identified.

Systematic sampling is used when conducting an intensive soil survey. Transects begin at an identifiable point on the site and run perpendicular to the contours of the site to cover as much variability as possible. Transects are spaced 40m apart and run parallel to one another. Two surveyors running parallel transects have proven optimal for field mapping operations. Soil sampling is conducted along the transects at 20 m to 60 m intervals, the distance depending on the topography and soil variability. Soil types are differentiated on the basis of soil texture, depth, drainage, and stoniness in the A, B, and C horizons.

The first soil type to be encountered on a property is to be identified on the map with a capital letter A. Other types must be lettered consecutively as they occur. The location of soil type boundaries is determined by extra sampling between two dissimilar spot samples. A closed legend should be used for each site as soil type A on one site will not necessarily correspond to soil type A on another.

The minimum area to be delineated as a separate soil type is 800 square meters. Each soil type that exceeds an area of 800 square metres over the entire site requires a complete profile description. Soil pits must be located

and excavated in a representative area of the soil type being described and its position noted on the field map. The soil pit should be a minimum of one metre deep to reach the C horizon and have a pit face one metre wide. The pit should be excavated so that the profile will receive the maximum exposure to light when being described. Once the description is complete the pit should be refilled immediately to decrease the risk of danger to animals, people and equipment.

The standards to be used in describing soil profiles are given later in this chapter.

The accurate delineation of natural property boundaries and landmarks are essential for proper management of the site. The following, although not all-inclusive, represents the natural property boundary and landmark information which must be accurately delineated in the mapping operation and subsequently shown on the final soil survey maps: fences, hedgerows, drainage ditches, single trees in sub-compartments, rock piles, exposed bedrock, access roads, hydro lines, pipelines, woodlots, swamps, buildings and other obstructions to operations.

SOIL PROFILE DESCRIPTION CRITERIA

Soil attributes in the exposed soil profile must be described for each horizon. When an attribute is not present for a particular criteria or not applicable, a slash (-) is used to indicate its absence. A blank may be interpreted as an oversight of the criteria on the part of the soil surveyor. Soil profile description criteria are detailed in this section. Refer to Table 3-1 for a graphic example of a soil profile description.

Soil Horizon Designations

Soil horizons are differentiated primarily on the basis of differences in colour, texture, coarse fragments and mottling. They are designated by capital letters which show the relationship among horizons. Lowercase suffixes must be used to specify each horizon (eg. Ap) as defined by Dumanski (1978).

Depth Measurements

Measurements are taken at the upper and lower limit of a horizon. When the boundary between horizons is not smooth, measurements will be made at a

TABLE 3-1

EXAMPLE OF SOIL PROFILE DESCRIPTION SHEET

SOIL PROFILE DESCRIPTION

PROPERTY : INDUSTRY 100 SURVEYORS : WX & YZ

SOIL TYPE : A GUELPH SERIES : ANON Sa Lo DATE : 6/1/84

HORIZON		Ap	Bf	Cg		
DEPTH (cm)		0 – 30	30 – 55	55 – 100		
BOUNDARIES	WIDTH	Clear	Clear			
	TOPOGRAPHY	Smooth	Smooth			
COLOUR	WET	7.5 YR 3/0 Very Dark Grey	7.5 YR 5/4 Brown	7.5 YR 6/2 Pinkish Grey		
	MOIST	7.5 YR 3/2 Dark Brown	7.5 YR 5/4 Brown	7.5 YR 6/2 Pinkish Grey		
TEXTURE		Sandy Loam	Sand	Sandy Clay Loam		
STRUCTURE	GRADE	Weak	Weak	Moderate		
	KIND	Granular	Single Grain	Sub-Ang Blocky		
	CLASS	Fine	—	Fine		
CONSISTENCE	STICKINESS	Non Sticky	Non Sticky	Sticky		
	PLASTICITY	Non Plastic	Non Plastic	Plastic		
	MOIST	Very Friable	Loose	Friable		
CEMENTATION		—	—	—		
DRAINAGE CLASS :		Imperfectly Drained				
MOTTLES	ABUNDANCE	—	Common	Common		
	SIZE	—	Medium	Fine		
	CONTRAST	—	Distinct	Prominent		
ROOTS	ABUNDANCE	Plentiful	Few	—		
	DIAMETER	Very Fine	Micro	—		
	ORIENTATION	Oblique	Vertical	—		
	DISTRIBUTION	Inped	—	—		
	SPECIES	Herbaceous	Herbaceous	—		
PORES	ABUNDANCE	Common	Common	Few		
	DIAMETER	Fine	Fine	Micro		
FREE CARBONATES		—	—	—		
COARSE FRAGMENTS	NAME	—	—	—		
	ABUNDANCE	—	—	—		
SOIL REACTION – pH		6.0	6.1	6.2		

mid-point between the upper and lower limit of the boundary. Depths are recorded to the nearest centimeter and recorded as a range (eg. 20-42 cm).

Boundaries

Boundaries between soil horizons will be described according to their distinctness and form (Dumanski, 1978).

Distinctness	Abruptness of vertical changes (cm)
Abrupt	< 2
Clear	2-5
Gradual	5-15
Diffuse	>15

Form	Variations of boundary plan
Smooth	Nearly a plane
Wavy	Pockets wider than deep
Irregular	Pockets deeper than wide
Broken	Some parts are unconnected

Colour

For each horizon the predominant colour of the soil matrix will be recorded for moist and wet conditions. Wet is described as being moisture levels at or slightly above field capacity. Moist is a moisture content between air dry and field capacity.

Soil colour is described according to its hue, value and chroma as defined by a Munsell Colour Chart (Munsell, 1954) (eg. 10 YR 5/6 yellowish-brown).

Texture

Particle size distribution (by percent weight) is described according to twelve standard textural classes specified in Table 3-2.

TABLE 3-2:

SOIL TEXTURE CLASS DESCRIPTION CRITERIA

Texture	Symbol	Range in Percent Weight
Sand	Sa	85 - 100% sand 0 - 15% silt 0 - 10% clay
Loamy Sand	Lo Sa	70 - 90% sand 0 - 30% silt 0 - 15% clay
Sandy Loam	Sa Lo	43 - 80% sand 0 - 50% silt 0 - 20% clay
Loam	Lo	23 - 52% sand 28 - 50% silt 7 - 27% clay
Silt Loam	Si Lo	0 - 50% sand 50 - 88% silt 0 - 27% clay
Silt	Si	0 - 20% sand 80 - 100% silt 0 - 12% clay
Sandy Clay Loam	Sa Cl Lo	45 - 80% sand 0 - 28% silt 20 - 35% clay
Clay Loam	Cl Lo	20 - 45% sand 15 - 53% silt 27 - 40% clay
Silty Clay Loam	Si Cl Lo	0 - 20% sand 40 - 73% silt 27 - 40% clay
Sandy Clay	Sa Cl	45 - 65% sand 0 - 20% silt 35 - 55% clay
Silty Clay	Si Cl	0 - 20% sand 40 - 60% silt 40 - 60% clay
Clay	Cl	0 - 45% sand 0 - 40% silt 40 - 100% clay

Source: U.S.D.A., 1960

Structure

Soil structure refers to the combination and arrangement of primary soil particles into peds (Armson, 1977). Structure is described according to grade, kind and class as defined below (Dumanski, 1978).

Grade of Structure

- Weak - weakly formed peds, barely observable in place
- Moderate - moderately well-formed peds, moderately evident in place
  - when soil is disturbed peds break down into a mixture of many distinct, entire peds, with some broken, some disaggregated, material
- Strong - strongly formed peds evident in undisplaced soil
  - when the soil is disturbed peds adhere to one another and withstand displacement and separation
  - when disturbed the result is entire peds and little disaggregated material

Types and Classes of Structure

The types and classes of soil structure are described according to Table 3-3.

Cementation

Cementation refers to a brittle, hard consistence caused by a cementing agent, such as humus, calcium carbonate, or oxides of iron, silica, and aluminum. The degree of cementation is described according to the following criteria (Dumanski, 1978):

- Weakly cemented: Wet, cemented mass is brittle and hard, but can be broken in the hands.
- Strongly cemented: Wet, cemented mass is brittle and harder than can be broken in the hand, but is easily broken with a hammer.
- Indurated: Wet, cementated mass is brittle and so strongly cemented that a sharp blow with a hammer is required for breakage.

TABLE 3-3:

TYPES AND CLASSES OF SOIL STRUCTURE

TYPE	KIND	SHAPE	CLASS				
			VERY FINE	FINE	MEDIUM	COARSE	VERY COARSE
STRUCTURELESS No observable aggregation or no definite orderly arrangement around natural lines of weakness	SINGLE GRAIN Loose incoherent mass of individual particles as in sands		-	-	-	-	-
	AMORPHOUS (massive) A coherent mass showing no evidence of any distinct arrangement of soil particles		-	-	-	-	-
BLOCKLIKE Soil particles are arranged around a point and bounded by flat or rounded surfaces	ANGULAR BLOCKY Faces rectangular and flattened, vertices sharply angular		< 5mm	< 10mm	10-20mm	20-50mm	>50mm
	SUBANGULAR BLOCKY Faces subangular, vertices mostly oblique or subrounded		< 5mm	< 10mm	10-20mm	20-50mm	>50mm
	GRANULAR Spheroidal and characterized by rounded vertices		< 1mm	< 2mm	2-5mm	5-10mm	-
PLATELIKE Soil particles are arranged around a horizontal plane and generally bounded by relatively flat horizontal surfaces	PLATY Horizontal planes more or less developed		< 1mm	< 2mm	2-5mm	>5mm	-
PRISMLIKE Soil particles are arranged around a vertical axis and bounded by relatively flat vertical surfaces	PRISMATIC Vertical faces well defined and edges sharp		< 10mm	< 20mm	20-50mm	50-100mm	>100mm
	COLUMNAR Vertical edges near top of columns are not sharp (columns may be flat-topped, round-topped, or irregular.		< 10mm	< 20mm	20-50mm	50-100mm	>100mm

Source: Ontario Institute of Pedology, 1980

Consistence

Soil consistence is a term used to describe the physical condition of a soil at various moisture contents, as exhibited by the behaviour of that soil toward mechanical stresses or manipulations (Brady, 1974). Consistence is described in the wet and moist condition.

Consistence When Wet - Consistence when wet is determined at moisture levels at or slightly above field capacity, and is described in terms of stickiness and plasticity (Dumanski, 1978).

A. Stickiness - Stickiness is the quality or degree of adhesion to other objects or materials. For field evaluation of stickiness, soil material is pressed between thumb and finger and its adherence is noted.

Degree of stickiness is described as follows:

- Non-sticky: After release of pressure, practically no soil material adheres to thumb and finger.
- Slightly sticky: After pressure has been applied, the soil material adheres to both the thumb and finger, but comes off one or the other rather cleanly. The soil is not appreciably stretched when the digits are separated.
- Sticky: After pressure has been applied, the soil material adheres strongly to both the thumb and finger and tends to stretch somewhat and pulls apart rather than pulling free from either digit.
- Very sticky: After pressure has been applied, the soil material adheres strongly to both the thumb and forefinger and is decidely stretched when they are separated.

B. Plasticity - Plasticity is the ability of a soil to change shape continuously under the influence of an applied stress, and to retain the impressed shape on removal of the stress. For field determination of maximum plasticity the wet sample is crushed in the hand and manipulated to determine if a roll can be formed. The minimum thickness of a suspended roll 4 cm long that can support its own mass when suspended and the relative resistance to deformation of that roll are used to determine maximum plasticity class.

- Non-plastic: A roll 4 cm long and 4 mm thick cannot be formed.
- Slightly plastic: A roll 4 cm long and 4 mm thick can be formed, but cannot support its own mass. Soil mass easily deformable.
- Plastic: A roll 4 cm long and 2 mm thick can be formed, but cannot support its own mass. Moderate pressure required for deformation of soil mass.
- Very plastic: A roll 4 cm long and 2 mm thick can be formed, and can support its own mass. Strong pressure is required for deformation of soil mass.

Consistence When Moist - Consistence when moist is determined at a moisture content approximately midway between air dry and field capacity (Brady 1974 and U.S.D.A. 1960). To evaluate this consistence, select and attempt to crush between the thumb and forefinger a mass that appears slightly moist.

- Loose: Soil material non coherent.
- Very Friable: Soil material crushed under very gentle pressure, but coheres when pressed together.
- Friable: Soil material crushed easily under gentle to moderate pressure between thumb and forefinger, and coheres when pressed together.
- Firm: Soil material crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.
- Very firm: Soil material crushes under strong pressure between thumb and forefinger.
- Extremely firm: Resists crushing between thumb and forefinger.

Mottles

Mottles result when the soil has been saturated with water for most or part of the year. The result is the oxidation and/or reduction of certain minerals, such as iron and manganese. The pattern of mottling is described in terms of abundance, size and contrast (Dumanski, 1978).

Abundance

- Few - Mottles occupy less than 2% of the exposed surface.
- Common - Mottles occupy 2 to 20% of the exposed surface.
- Many - Mottles occupy more than 20% of the exposed surface.

Size

Fine - Less than 5 mm in width or diameter.

Medium - 5 to 15 mm in width or diameter.

Coarse - Greater than 15 mm in width or diameter.

Contrast

	Dissimilarity from Matrix in Units		
	Hue	Value	Chroma
Faint	-	-	-
Distinct	2.5	1	1
Prominent	5	3	3

Drainage

Soil drainage classes are based primarily on the internal drainage of the soil, although transmissibility and run-off must also be considered. Internal drainage is that quality of a soil that permits the downward flow of excess water through it and is reflected in the frequency and duration of periods of saturation with water (U.S.D.A., 1952). Transmissibility is that quality of the soil that enables it to transmit water or air. Runoff refers to the relative rate of water removed by flow over the surface of the soil (U.S.D.A., 1952).

Drainage is determined according to the following drainage classes:

Well-drained (WD). The water moves readily through the horizon, with a moderately rapid vertical transmissibility and a moderate seepage rate in medium sloping areas. The soils in this category are usually medium-textured, and deep. Internal drainage is medium to rapid, with limited persistence and a deep water table. The B horizon are usually reddish, brownish or yellowish in colour. Soils are free from mottling in the upper metre.

Moderately well-drained (MWD). The soil moisture in excess of field capacity remains in the soil for a short period of the year. This is due to one or a combination of factors: 1) moderate vertical transmissibility due to an impeding layer, 2) relatively flat topography, or 3) higher water table. Internal drainage is medium, with good persistence. The soils are commonly mottled in the lower B horizon or below 65 cm. Soils are medium or fine textured and usually deep. In old fields, the B and C horizons are often faintly mottled. In coarser textured soils, moisture is often supplemented by seepage.

Imperfectly drained (ID). Water is removed slowly from the soil, and therefore, the soil is kept wet for a signficant part of the growing season. Excess water will move slowly downward; the vertical transmissibility is medium to low. The usually high water table or seepage source (i.e., coarse soil), keeps the soil relatively wet throughout the greater part of the growing season. Persistence is very high. In coarser soils, where persistence is somewhat lower, the contribution of sub-surface flow of a water table is increased. The available moisture is variable, as is texture and internal drainage is usually slow. Imperfectly drained soils are gleyed versions of well-drained subgroups. Soils are often intensely mottled in the B and C horizons, and, less frequently, in the A horizon.

Poorly drained (PD). Water remains within the soil for a large part of the year. Excess water is evident in the soil. Transmissibility is low, but lateral seepage could be present. The soil is gleyed, with very faint to prominant mottling. A perched water table is sometimes evident.

Very poorly drained (VPD). The removal of water is so slow that water remains on or above the surface for the large part of the year. Ground water and seepage are the main sources of water, with precipitation being important where a perched water table exists. A very strong gley layer develops, with mottling evident in the A horizon.

Roots

Roots found in the soil profile are described with respect to their abundance, diameter, orientation, distribution and species (Dumanski, 1978). These categories are defined below the reference unit area surface is 2.5 cm square for micro, very fine and fine pores and 1 m square for medium and coarse roots.

Abundance	No./unit area surface
Very few	>1
Few	1-3
Plentiful	4-14
Abundant	>14

Diameter	Size (mm)
Micro	<0.075
Very Fine	0.075-1
Fine	1-2
Medium	2-5
Coarse	>5

Orientation

Vertical - orientation mainly vertical
Horizontal - orientation mainly horizontal
Oblique - orientation mainly oblique
Random - orientation in all directions

Distribution

Inped - most roots are within peds
Exped - most roots follow ped interfaces

Species

The most abundant plant species are recorded.

Pores

As with roots, pores are described with respect to their abundance and size. The reference unit area surface is 2.5 cm square for micro, very fine and fine pores and 1 m square for medium and coarse pores (Dumanski, 1978).

Abundance	No./unit area surface
Very few	<1
Few	1-3
Common	4-14
Many	>14

Diameter	Size (mm)
Micro	> 0.075
Very Fine	0.075-1
Fine	1-2
Medium	2-5
Coarse	>5

Free Carbonates

The presence or absence of free carbonates is determined by applying a few drops of HCL (10%) to the soil sample. The degree of calcareousness will be reflected in the degree of effervescence as described below (Dumanski, 1978).

Very weak - few bubbles

Weak - bubbles readily observed

Moderate - bubbles form low foam

Strong - bubbles form thick foam

Coarse Fragments

Coarse fragments are described according to their abundance and size on a horizon basis. The chart below lists the various fragment names with an accompanying size description (Dumanski, 1978).

Fragment Name	Size
Gravel	up to 7.5 cm in diameter
Cobbly	7.5 to 25 cm in diameter
bouldery	more than 25 cm in diameter

Abundance

Abundance is estimated and recorded as a percentage by volume for each horizon.

Soil Reaction - pH

Soil reaction records the active hydrogen ions in the soil and is measured in pH units. pH must be determined for each horizon in every soil type. Soil reaction measurements must be made under laboratory conditions and recorded to an accuracy of one decimal place (eg. pH 6.7).

Soil Profile Diagram

Other features which were not described on the profile description sheet must be recorded under the COMMENTS section on the soil profile diagram (see Figure 3-1). Evidence of soil compaction, high levels of organic matter, and the depth, thickness and mineral composition of hardpans should be noted.

A profile diagram must be sketched showing the following features (if applicable):

- depth of water table
- horizon boundaries and topography
- live and decomposing roots
- evidence of microbial activity
- mottles
- course fragments
- weathered rocks
- sea shells
- concretions
- charcoal layers
- hardpans

The symbols to be used to illustrate the soil profile features are shown in Table 3-4.

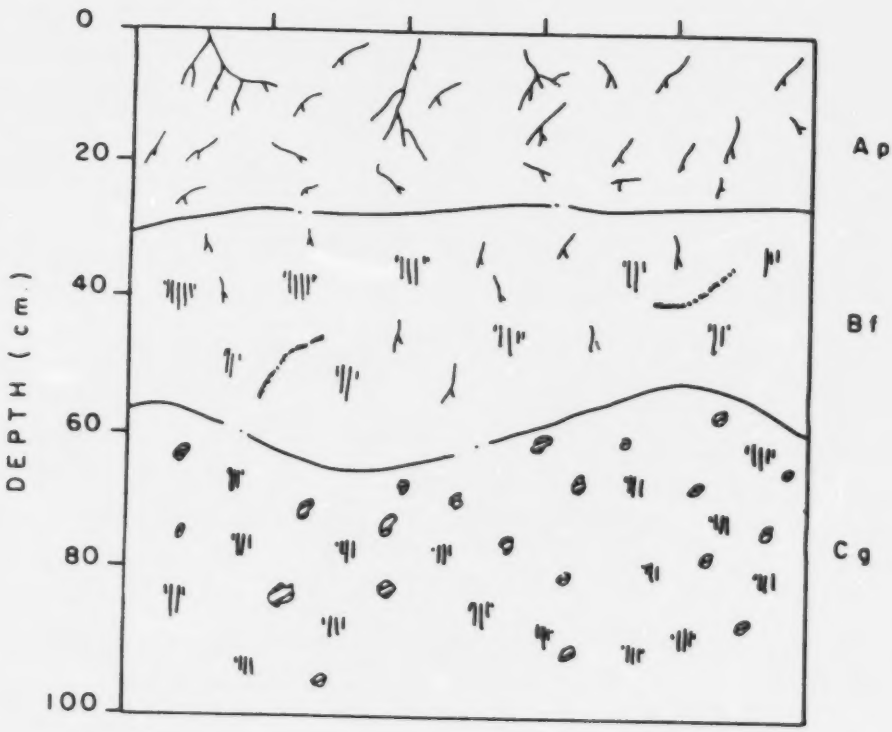
FIGURE 3-1

PROFILE DIAGRAM TO ACCOMPANY SOIL PROFILE DESCRIPTION IN TABLE 3-5

PROPERTY INDUSTRY 100

SOIL TYPE A DATE 6/1/84

SURVEYED BY WX & YZ



COMMENTS:

- field ploughed and disced
- patches of quackgrass in juvenile stage scattered over the area

TABLE 3-4:

SYMBOLS TO DELINEATE SOIL PROFILE FEATURES

- HORIZON BOUNDARIES:

WIDTH		TOPOGRAPHY	
Abrupt	———	Smooth	———
Clear	—·—·—	Wavy	~~~
Gradual	— — —	Irregular	~~~
Diffuse	- - - - -	Broken	

- ROOTS
- CONCRETIONS
- CEMENTATION
- COARSE FRAGMENTS
- DECOMPOSING STONE
- WORM TUNNEL
- DECOMPOSING ROOTS
- MOTTLES
- SHELLS
- GROUND WATER LEVEL
- VARIOUS TEXTURAL BANDING
- CALCIUM ACCUMULATION FRONT

FINAL SOIL SURVEY REPORT

The final soil survey report must consist of the following:

- field notes including mapping sheets
- soil profile description and diagram sheets for each soil type
- final intensive soil survey map drafted at a scale of 1.4000 and
- a property summary

The property summary should include a description of the physical characteristics of the site (i.e., physiographic features, topography, local hydrology, local natural vegetation) and the characteristics and extent of different soil types encountered. An example of a property summary is presented in Appendix 2.

The information that must appear on the final intensive soil survey map is graphically presented in Figure 3-2 and is listed below.

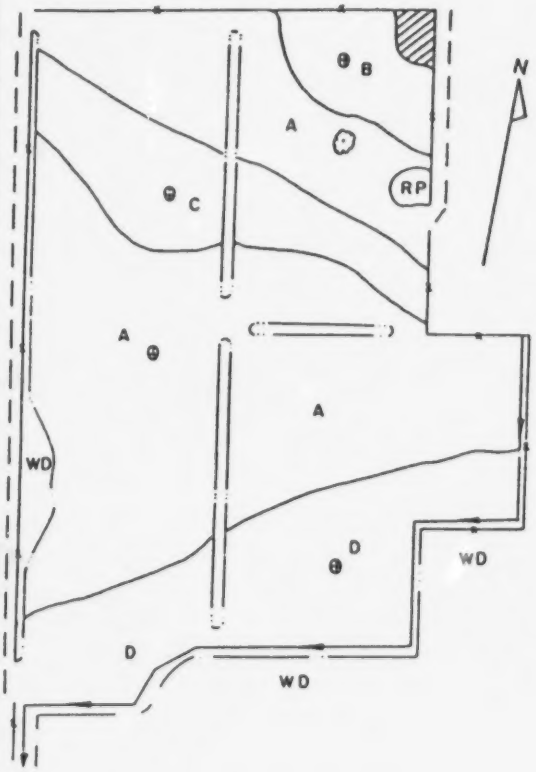
- Title - F.G.H. Intensive Soil Survey
- Scale - 1:4000
- Area - total area of the property in hectares
- North arrow
- Property name (eg. Industry 100)
- Lot and Concession
- Township
- Administrative District
- All property features
- Soil type delineation
- Soil type letter designations
- Soils data (texture, depth, drainage and area in hectares)
- Name of consulting firm
- Date drafted

Maps should always be produced so that the north arrow points to the top of the page. Appendix 3 presents criteria for drafting a final soil survey map.

FIGURE 3-2:

EXAMPLE OF PLANTATION SITE AS DELINEATED BY INTENSIVE SOIL SURVEY

F. G. H. INTENSIVE SOIL SURVEY



INDUSTRY 100
LOT 1, CONC. V
ANON TOWNSHIP
ANON DISTRICT

A – Sandy Loam (0–30) / Sand (30–55) / Sandy Clay Loam (55–100)
– Imperfectly Drained
– 7.4 ha.

B – Sandy Loam (0–20) / Sand (20–45) / Sandy Clay Loam (45–100)
– Moderately Well Drained
– 0.6 ha.

C – Loamy Sand (0–15) / Sand (15–58) / Sand (58–69) / Sandy Clay Loam (69–100)
– Well Drained
– 1.4 ha.

D – Loam (0–40) / Sandy Clay Loam (40–65) / Clay (65–100)
– Poorly Drained
– 2.6 ha.

Total Area: 13.4 ha.

Scale 1 : 4000

LANDMAN CONSULTANTS, LTD.

MAY, 1984.

APPENDICES

APPENDIX 1

SOIL SURVEY CONTRACT

An intensive soil survey legal contract package has been developed and refined since 1982. This contract has been used primarily by the Ministry of Natural Resources to enter into agreement with private consulting firms to provide soil survey operations on fast growing hardwood production sites.

The contract package consists of:

(1) a legal contract specifying the administrative particulars of the agreement.

(2) a Schedule A, which specifies the technical requirements of the contract. This includes a concise description of services to be met by the contractor and two appendices which represent the more detailed criteria and procedures to be followed.
These appendices are presented in Chapter 3 (Soil Survey Standards); Appendix 1 consists of the soils standards and Appendix 3 given later in this publication; Appendix 2 consists of an example of a final soil survey report (a combination of Appendix 2 given later in this publication, Figures 3-1 and 3-2 and Table 3-1).

(3) a Schedule B which specifies the properties/sub-compartments to be soil surveyed under the contract.

The aforementioned legal contract is presented within this Appendix.

CONTRACT NO. _____

AGREEMENT made in triplicate this day of

BETWEEN:

HER MAJESTY THE QUEEN in right of Ontario as represented by the Minister of Natural Resources, hereinafter referred to as the "Crown".

- AND -

_____

a corporation incorporated under the laws of Ontario, having its head office in the City of hereinafter referred to as the "Contractor".

WHEREAS the Contractor has agreed with the Crown to perform a soil survey within the Administrative District of . of the Ministry of Natural Resources in accordance with the provisions of this agreement;

NOW THEREFORE in consideration of the mutual provisions of this agreement, the Crown and the Contractor agree each with the other as follows:

1. The Crown and Contractor agree that in this agreement,
   (a) "parties" means the Crown and Contractor; and
   (b) "soils survey" means the soil survey referred to in Schedule "A" on areas referred to in Schedule "B" to this agreement.

2. The Contactor agrees to perform the soil survey and agrees to commence the soil survey on the day of . 19 and to complete the soil survey on or before the day of . 19 .

3. (1) Provided that monies are appropriated therefore by the Legislature of Ontario, the Crown agrees to pay the Contractor up to a maximum of _____dollars of lawful money of Canada for the performance of all the obligations of the Contractor under this agreement.

(2) The Contractor agrees to prepare and submit to the Crown progress invoices in triplicate at the end of each week of the term of this agreement and agrees to set out in each such invoice a brief description of the work performed, the total amount of the invoice and such other matters as the Crown may reasonably require. Invoices shall be prepared in accordance with the same invoice referred to in Schedule "C".

(3) Subject to subparagraph 4, the Crown agrees to pay invoices submitted by the Contractor under subparagraph 2 as soon as reasonably possible after the receipt and approval of such invoices.

4. The contractor agrees to deposit with the Crown a certified cheque for , payable to the Treasurer of Ontario to secure the due performance by the Contractor of this agreement, and the Crown agrees to return the deposit without interest upon the due performance by the Contractor of this Agreement.

5. The Construction Lien Act, as amended, applies in respect of the performance of this agreement, and the Contractor agrees that the Crown must hold back 10% of the value of the work performed under this agreement for a period of 45 days after this agreement has been completed or abandoned.

6. The Crown may from time to time until the completion of all work referred to in this agreement, issue an addendum or addenda that may have the effect of clarifying, varying or adding to the soil survey, and the Contractor agrees to furnish, as soon as reasonably possible after the receipt of each addendum, to the Crown an accurate estimate of the additional charges, if any, required by the Contractor to comply with the provisions of the addendum, and the Contractor upon receipt of the Crown's written approval of the additional charges, agrees to comply with the requirements of the addenda and the Crown agrees subject to the provisions of paragraph 3 in respect of invoices and holdbacks, to pay the additional charges to the Contractor.

7. (1) The Contractor agrees to prepare and submit to the Crown on or before the day of , 19 a final typewritten and drafted report in triplicate in respect of the soil survey performed under this agreement, and without limiting the foregoing, agrees that the final report shall include all data, maps and information specified in Schedule "A" for each property listed in Schedule "B".

(2) The Crown and Contractor agree that the Crown may from time to time until the completion of all work referred to in this agreement, conduct an audit of the soil survey field operations while the operations are in progress. A report will be prepared by the Crown at the time and place of the audit documenting the adherence of the Contractor to the specifications of the soil survey referred to in schedule "A" of this agreement and this report will be read and amended as required by the Contractor and signed as a token of their adherence thereto. The filing of two audits of non-compliance by the Contractor will indicate that the Contractor is not fulfilling the conditions of this agreement and therefore the contract will be terminated as of the date of the last audit report and the Contractor be paid for work completed to that date in accordance with this agreement.

8. The Contractor agrees that it will not, directly or indirectly, disclose or use at any time, either during or subsequent to the term of this agreement, any secret or other confidential information, concerning the Crown's procedures, methods, formulae, apparatus, specifications, materials, clients and their identities and requirements, discoveries, inventions, patents (including applications and rights in either), contracts, finances, personnel, their duties and capabilities, research, plans, policies and intentions, including matters, the dissemination of a knowledge whereof might prove prejudicial to the Crown, except that the Contractor may disclose any information reasonably necessary to the fulfillment of its obligations under this agreement.

9. The Contractor agrees with the Crown that all and any reports, maps and documents prepared under this agreement or any extension of this agreement, relating or in any way appertaining to or connected with the soil survey shall be the sole and exclusive property of the Crown and the Contractor agrees, whenever requested to do so by the Crown to execute, or arrange for the execution by any other person of, any and all applications, assignments, and other instruments which the Crown shall deem necessary in order to apply for and obtain the copyright in Canada or any foreign country in such reports, maps and documents and in order to assign and convey to the Crown the sole exlusive right, title and interest in and to such reports, maps, documents, applications and copyrights.

10. (1) The Contractor agrees to comply fully with all the requirements of the Workmen's Compensation Act and without limiting the generality of the foregoing, agrees to pay all assessments made under the said Act against the Contractor.

(2) When the Contractor personally performs labour under this agreement, the Contractor agrees to apply to the Workmen's Compensation Board for personal coverage.

(3) When the Contractor fails to pay the assessments made under the said Act, the Contrator agrees that the Crown may deduct the amounts of the said assessments from any monies payable or returnable to the Contractor under this agreement and may pay such amounts to the said Board.

(4) The Contractor agrees to provide on the request of the Crown, satisfactory proof of compliance with subparagraphs 1 and 2.

11. The Contractor agrees to fully indemnify and save harmless the Crown from and against all claims, demands, judgements, losses and costs, damages and expenses which at any time or times the Crown may bear, sustain, incur, suffer, receive or be put to for or by reason of or on account of any negligent act or omission of the Contractor or the employees or any of them.

12. The Contractor agrees that the failure of the Crown to insist, in one or more instances, upon the performance by the Contractor of any of the terms of conditions of this agreement shall not be construed as a waiver of the future performance of any such term or condition and the obligation of the Contractor with respect to such future performance shall continue in full force and effect.

13. The Contractor agrees in respect of the performance of this agreement to comply with all federal and provincial laws, rules, orders and regulations and all rules, orders, regulations and by-laws of all relevent local authorities.

14. (1) During the entire term of this agreement, the Contractor agrees to have in force a general public liability and property damage insurance policy or policies with a limit of at least $500,000 for each occurrence that protects the Contractor against claims arising out of any act or omission of the Contractor, any employee of the Contractor, or any of them, in the performance or intended performance of this agreement.

(2) The Contractor agrees with the Crown to have the said policy or policies endorsed,

(a) to name her Majesty the Queen in right of of Ontario and Her servants and officers, as additional insureds;

(b) to provide that the insurance shall apply it the same manner as though separate policies were issued in respect of any action or claim brought against any of the insureds by any other insured or by an employee of such other insured; and

(c) to provide that no cancellation of the insurance shall be made except on at least 15 days notice from the insurers to the Crown

(3) Upon the commencement of this agreement, the Contractor agrees to provide the Crown with a duly certified true copy of the policy or policies of insurance referred to in subparagraph 1, endorsed in the manner referred to in subparagrpah 2.

15. The Contractor, for all purposes shall be an independent contractor and the employees of the Contractor shall be servants of the Contractor and not of the Crown.

16. The Crown, for the purposes of this agreement, may act through any officer or employee of the Ministry of Natural Resources.

17. The Contractor agrees not to assign or subcontract any part of the survey work without the prior written consent of the Crown.

18. This agreement shall be construed in accordance with the laws of Ontario.

19. Subject to paragraph 17, the parties hereto agree that this agreement shall be binding upon and enure to the benefit of the Crown, her heirs and successors and the Contractor and the Contractor's successors, assigns, executors, administrators and heirs, as the case may be.

IN WITNESS WHEREOF the duly authorized representatives of the Crown and Contractor have duly executed this agreement.

SIGNED, SEALED AND DELIVERED in the presence of	) HER MAJESTY THE QUEEN in right of Ontario
_____	) _____
as to the execution by the District Manager, District of the Ministry of Natural Resources	) District Manager as authorized by the Minister of Natural Resources
	) *
_____	) By: _____ xx
witness as to execution	) Position:
	) And: _____ xx
	) Position:
*Where the Contractor is a corporate body, insert here the full corporate name.	) xx Affix here red wafer seal for each individual Contractor

Schedule A

to the agreement between the Crown in right of Ontario and _____ _____. The Contractor agrees with the Crown to perform a soil survey within the Forest Administrative District on all specific lands in Schedule B and this soil survey shall include the following work:

Reconnaissance

1. Existing information on the survey area will be compiled from sources including geological maps and reports, topographic maps, road maps and any existing soil maps and reports.

2. Preliminary examination of aerial photographs of the area will be conducted to provide knowledge of the terrain types and their distribution patterns.

Field Surveying and Mapping

3. A systematic field survey of soil characteristics within the survey area (i.e. each specific compartment) will be conducted by a minimum of 2 surveyors each sampling at 20-60m intervals (depending on soil variability) along a transect line with transects being 40m apart. Surveyors examine the soil conditions at each inspection point and describe and record at each inspection point the textures of the various soil horizons, stoniness, drainage and depth (to an impervious layer), according to the accompanying soil classification and mapping requirements (Appendix I and II).

4. Soil profile pits (minimum $1m^2$ pit face) will be exposed and described for each different soil type identified in the field mapping. The accompanying soil description criteria must be used for the description of each pit.

5. Mapping units will be delineated on the basis of homogeneity of soil conditions, according to the accompanying soil classification at a scale of 1:2000 in the field and a minimum size of delineated area on the ground of 800 square meters.

6. For each mapping unit delineated under Item 5, a single letter will indicate the corresponding soil pit description.

7. The field mapping must include an accurate delineation of all hedgerows, boulder piles, exposed bedrock, single trees in subcompartments, access roads, fences and any other natural feature which will provide proper orientation and description of the property.

8. Quality control of field determination of soil texture by survey crews will be maintained through the laboratory determination of the particle size distribution of a minimum of three (3) check samples per property specified in Schedule B; these samples must be taken from an A, B and C horizon of the most representative soil pit described on the property (ie. the pit describing the most predominant soil of the property).

Final Report

9. For each property specified in Schedule B a final mylar drafted map at a scale of 1:4000 will be produced using the format in Appendices I and II.

10. The Contractor will provide a brief soil survey report for each property specified in Schedule B which will include information about the physical characteristics of the area (ie. geologic origins of parent material, topography, hydrology) the soils and the mapping units.

11. The Contractor will provide final typewritten soil description sheets for each soil type identified on each specific survey area, as well as corresponding soil profile diagrams.

APPENDIX 2

Example of Final Soil Survey Report

Industry 100
Lot 1, Conc. V
Anon Township
Anon District

Property Summary

Industry 100 lies within the Anon Sand Plain, a physiographic region noted for its sand ridges and clay-floored valleys. The depth of the sand ranges from 2 metres in the north part of the region to 10 metres in the south. Most of the clays in the region are poorly to very poorly drained. The sands are generally imperfectly to moderately well drained. Both the sands and the clays are stonefree. The area is underlain by limestone bedrock.

Four soil types were delineated and described on Industry 100. Soil type A comprises most of the mapped area (7.4 ha), and is imperfectly drained. Soil type B (0.6) occupies the northeast corner of the property and lies adjacent to exposed bedrock. Soil type C (1.4 ha) runs across the top half of the property and is drier than the rest of the area. Soil type D (2.6 ha) is imperfectly drained, fine-textured and has a high level of organic matter.

At the time of surveying, the property was ploughed and disced. Patches of quackgrass in the juvenile stage were evident in the drier portions of the property. Pure populations of horsetail in the juvenile stage formed carpets in Soil Type D. The property is divided into small fields by hedgerows comprised mostly of young ash and shrubs in healthy condition. The wooded areas to the south consist mostly of soft maple. A page wire fence in poor condition surrounds the property. An inefficient, shallow drainage ditch runs down the east side and across the south property boundary.

APPENDIX 3:

SOIL SURVEY FINAL MAP DRAFTING CRITERIA

Feature	Symbol	Pen Size
Fence		00
Vegetation Boundary		000
Exposed Bedrock		000
Access		000
Single Tree		000
Swamp		000
Rock Pile		000
Foundation		000
Wooded		00
Soil Pit		00
Drainage Ditch		00
Soil Type Boundary		0
North Arrow		0

APPENDIX 3: (cont.)

Data Type	Template	Pen Size
Title-F.G.H. Intensive Soil Survey	175-200 CL	2-3
Scale	100 CL	00
Area	100 CL	00
Property Name	175-200 CL	2-3
Lot and Conc.	175-200 CL	2-3
Township	175-200 CL	2-3
Administrative District	175-200 CL	2-3
Soil Type Letter Designations	100 CL	00
Soils Data	100 CL	00
Name of Consulting Firm	Variable	Variable
Date Drafted	80-100 CL	000-00

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POOR

QUALITY

ORIGINAL